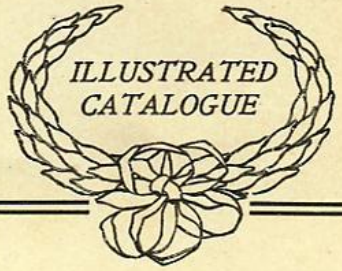
The Dayton Globe Iron Works Comp'y

ALEXANDER S. ADDISON
8 GRANITE ROAD
TEL SAUGUS 1342
SAUGUS, MASS.



Presenting the

New American Turbine

Manufactured by The Dayton Globe Iron Works Company

(Successors to Stout, Mills & Temple) also manufacturers of Paper and Pulp Mill Machinery: The Dayton Gas Engine: Beet Sugar Machinery: Gearing: Shafting: Pulleys

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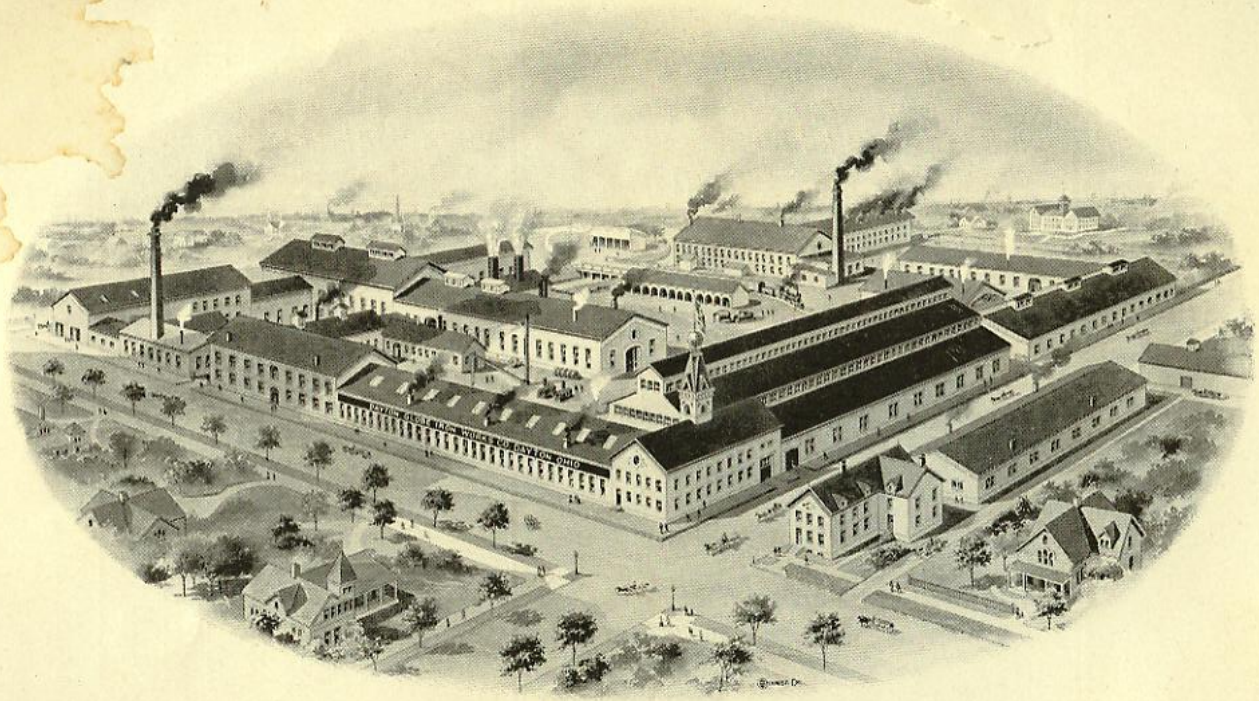

THE DAYTON GLOBE IRON WORKS CO., DAYTON, OHIO

ALEXANDER S. ADDISON
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TEL. SAUGUS 1342

Introductory

THE firm of Stout, Mills and Temple began business in doing a general mill-machinery business, includi manufacture of water wheels of the types known to days. In 1859 the American turbine wheel was pate and its manufacture begun. The sale and success of wheel was phenomenal, increasing in a short time from les than one per week to two per day. The reason for this success is easily explainable. The turbine, as such, had not yet attained recognized standing as a water wheel. Many makes were being brought forward, variations of the Fourneyron and Jonval, with all sorts of gate arrangements, each guaranteed superior to all others, but the results were unsatisfactory and unreliable. No two wheels of the same make performed alike. Flutter wheels, undershots, breast wheels, and overshots were in common use, and preferred on account of their more reliable performance. The advent of the American changed all this and ushered in a new era in wheel-building. The basis of the invention and patent of the American turbine was the application of the water to the wheel through graduated chutes made by gates hinged near the inside of the case, arranged about the periphery of the wheel and operated simultaneously by a system of levers attached to a central ring controlled by a hand-wheel and shaft through a segment rack and pinion. This permitted the water being admitted to the wheel from all points of the periphery and in greater or less quantities as required. The result was a wheel economical in the use of water and highly efficient, not only at full gate but especially so at part gate—the desideratum of a perfect turbine.

The advantages of a turbine over all other forms of water wheels were already known—economy in the use of water, greater velocity,

greater power for the diameter, durability, and that they suffered nothing by back water or freezing weather. It required only the advent of the American turbine to bring these facts home to the users of power and cause the former types to pass away. Hence the phenomenal success of the wheel. Buried under the waters of thousands of falls, in all parts of the globe, these American turbines are still forming work as silently, faithfully and efficaciously as forty years —a monument to the skill and mechanical ability of their makers. was it that the first and foremost of the turbine wheels of the d be styled the "American," and equally appropriate that of Stout, Mills and Temple should style themselves the e Iron Works."

imulated by the success of the American, other turbines followed. e American gate was imitated or copied, and register and ring ates foisted upon the market. As turbine-building developed, the testing of turbines was improved upon and reduced to a science, and the results of wheels carefully observed. About 1869, Mr. James Emerson began making a business of turbine-testing, first at Lowell, then at Holyoke, Mass. His appliances and methods were universally conceded the best and most accurate, and the Holyoke tests were accepted as authoritative. About fifty wheels of different makes were tested and the reports published, establishing the fact that the American turbine gave the highest results at full and part gates by from ten to twenty per cent over all others. This was sufficient to establish its reputation and the American became the standard by which all other turbines were compared. This position, having once been established for our wheel, has never been permitted to be lowered or supplanted.

Having established the fact that the American style of gate gave the best and only proper application of water to the runner for securing high, full and part gate results, all subsequent improvements were directed to improving and developing the correct lines for the curves of the buckets of the runner, for the purpose of securing greater power for the diameter, and at the same time, higher efficiency in that direction. Each successive experiment was carefully noted and recorded, so that today we have data and information undoubtedly possessed by no others. At least we are justified in this statement by our own results and the results of others. The American style of gate was maintained as stated, with such minor improvements as experience demonstrated as advisable, and is in use in the improved "New American Special" of today.

The demand for wheels of higher power for the diameter, brought forth in 1884 the New American turbine, a wheel embodying, as

intimated, the American gate and case, with a runner of improved form and greater capacity, the buckets so curved as to discharge downwardly, centrally and outwardly, instead of centrally only. This wheel developed about double the power of the American and other turbines with from four to five per cent more efficiency and maintained the reputation before established for high results at full and part gate. For ten years the New American continued to lead all other turbines as its predecessor had done for the previous quarter of a century.

In 1890 the firm of Stout, Mills and Temple, or the Globe Works, as they styled themselves, was reorganized and incorporated as The Dayton Globe Iron Works Company. With increased capital and facilities and renewed vigor and push, the new company forged ahead, not only in the further perfection and development of the New American turbine, but in the extension of their other lines of manufacture — power-transmitting machinery and machinery for paper and pulp mills, in which, likewise, we have acquired and maintained a high reputation. More recently has been added the manufacture of the Dayton gas and gasoline engine, and the manufacture of machinery for, and the construction and equipment of beet-sugar factories.

Our organization is perfect in every way, each department under the direction of capable executives, engineers of recognized ability and experience, the shops equipped with modern and up-to-date tools and facilities, and under the direction of capable superintendents and foremen. Stimulated by competition and the incentive to bring the turbine to its highest state of development, we have never relaxed our efforts nor spared any expense in the further improvement of our wheel. The same careful study and experiments, characterized by rewards of success as in the past, are being continued today. Since 1894 we have made great strides in the science and have distanced all competitors. The culmination of our labors for the present, we present to the users of water power in the improved New American Special, which we merely introduce here, referring all interested to the succeeding pages of this catalogue for a fuller acquaintance.

To the indefatigable labors of W. M. Mills (Vice-President of the Company and the inventor of the American turbine) is due not only the development and perfection of the "New American Special," but very largely the progress which has been made in turbine-building in the past forty years ; and he is today recognized as an expert in hydraulics and without an equal in the craft which he has made his lifework.

Construction of the New American Turbine

IN designing the New American turbine, we have combined the highest power and efficiency attainable, with a construction embodying simplicity, strength and durability. Long study, both theoretical and practical, demonstrated that efficiency was largely dependent on a proper application of water to the wheel, and that power was a question of capacity, the ability to discharge the largest amount of water in an efficient manner. The first was attained in the American gate and case, the latter in the runner of the New American Special.

In Fig. 1 is shown a horizontal section of runner, case and gates. The case consists of an upper and lower plate connected by fenders or gate guards and is cast in one piece. The gates are hinged at a point near the inside of the case, or point of depletion, and as the gates are opened or closed they form with the opposite fenders chutes which permit the water to enter in gradually expanding or contracting veins equally distributed around the wheel, and apply it against the buckets of the runner in a direction tangential to its periphery. It will be observed that the inner sides of the gate and fender, as well as the under side of the top plate of the case are so curved as to give to the mouth of the chute the shape of the "vena contracta" so that the water enters with the least resistance and passes through with the least friction, and in a solid mass without breaking. This principle of curved lines is followed throughout in both case and runner, the water nowhere encountering any abrupt angles from its entry to its discharge. The case contains from six to eleven chutes, depending on the size of the wheel, and of such size as to supply the wheel to its full capacity when the gates are full-open. It is to the peculiar construction or formation of these chutes that is due the high part-gate results

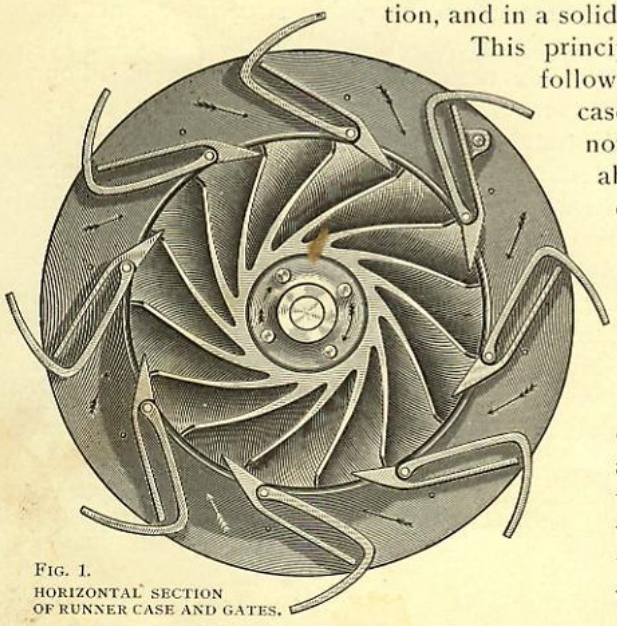


FIG. 1.
HORIZONTAL SECTION
OF RUNNER CASE AND GATES.

of the New American wheel. By a slight juxtaposition of the chutes the results could be entirely changed so that the wheel would develop even higher percentage of useful effect at full-gate than is now obtained at the best part-gate, but this would be at a sacrifice of efficiency at part-gate, and, as part-gate is the great desideratum, and as all users of water know that it is at from seven-eighths to three-fourths gateage that a turbine is generally run, in order that there may be a surplusage of power for contingencies, or when the wheel is affected by scarcity of water or by back water, or for regulation, we prefer to sacrifice at full-gate to gain the more desirable end of high percentage at part-gate. This matter is so well understood by all users of power that it is scarcely necessary to comment upon it.

Fig. 2 is a cut of the runner keyed to its shaft. The wheel was formerly made with steel buckets which were set in the mold and the rim and hub cast to them. This make of wheel proved deficient in strength for high heads, as experience soon demonstrated that wheels made in that manner, or in which the buckets are made of steel or cast separately of iron, and held to the rim by bolts, screws or rivets (which, by the way, is the practice of most builders today) are unable to stand the pressure of high heads. Sooner or later the buckets become detached from the rim and the total collapse of the wheel is but a question of a short time. The New American wheel as now made is a solid or continuous casting, formed entirely by dry sand cores, the result of which is a perfect wheel with even, true and smooth surfaces, and of unquestioned strength, and we guarantee them to stand the pressure of any head. The sixty-inch wheel-casting weighs considerably more than six thousand pounds, and other sizes are proportionately heavy, which gives some idea of their enormous strength; and being made entirely by dry sand-cores, all wheels of the same size are exact duplicates.

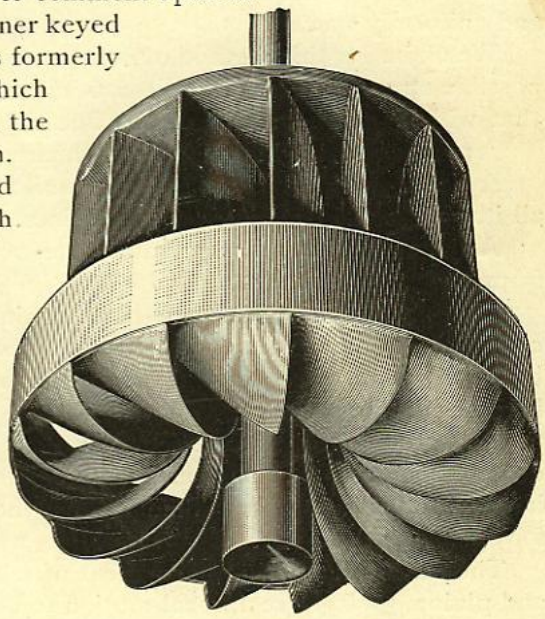


FIG. 2.
THE WHEEL REMOVED FROM CASE.

This method of molding wheels is original with ourselves, and so far as we know the New American is the only wheel so made. It involves difficult pattern-work in the construction of the proper core-boxes, requiring accuracy and skill of the highest order in core-making and molding, consequently costs more in its construction than the flimsy affairs which are cast separately and bolted together. On the other hand, it is vastly superior and more to be desired.

Each core is made in the same core-box, of a mixture of sharp river-sand and other ingredients to give consistency, coated with a core-wash and baked for several days in a core-oven until thoroughly dry. They are then set up and carefully spaced by gauge, so that when cast, the buckets of the wheel are of an even, uniform thickness and uniformly spaced.

We claim for this method of construction: A runner of the greatest possible strength, being a single continuous casting, therefore a runner that will stand the strain of any head.

A runner with buckets of uniform thickness, of smooth, even surfaces.

A runner with all its openings of uniform size and shape, and with all its curves of identically the same lines.

A runner that is an exact duplicate of every other runner made from the same pattern.

That part of the upper case-plate or rim which extends above the curved top of the chutes as shown in full view of case, Fig. 4 and Fig. 5, is bored to gauge, to receive the dome or crown-plate, the edge of which is turned to the same gauge and rabbeted to fit it, thereby relieving the set-screws of all transverse strain, their office being simply to hold down the dome, consequently it cannot become loose, a very important feature. The dome carries the ring, levers and segment for operating the gates.

The ring is moved in the segment of a circle by means of segment and pinion, giving a reciprocal motion to the levers, thus opening and closing the gates, which is clearly shown in the cut. Fig. 1 shows how the gates are hung, the inside end of the gate forming a hinge with adjacent part of the fender, similar to the hinge of a door. This construction has been so improved that the pin cannot become loose, nor in case of breakage by accident or from wear can the pin leave its socket or the gate become disengaged and cause damage by entering the wheel. The hinge pin is made with a **T** head, through which it is set-screwed to the top of the case. The fenders or guards behind the gates relieve them from the hydrostatic pressure of the head, consequently they are easily opened and closed by the ring and levers, and under ordinary heads are easily controlled by a governor.

Under high heads and where close regulation is required the action of the gates is further facilitated by the use of our improved gate balance, fully described further on. The ring is cast in one piece, with a continuous double flange, or two projecting plates, between which is held one end of the levers by a cap-screw passing through both flanges, which prevent the levers from becoming detached.

The ring fits as a collar about the neck of the dome, which is turned and faced off to receive it, and is also faced on top to receive the follower box, the lower flange of which projects over the ring, thus holding it in place.

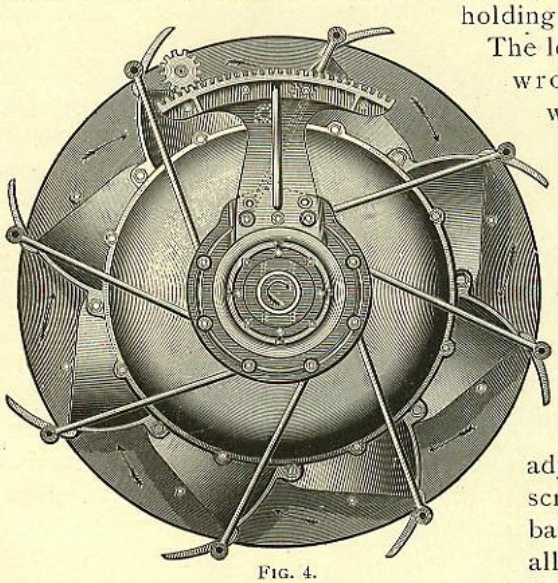


FIG. 4.
SHOWING CROWN PLATE AND GATE OPERATING MECHANISM.

The levers are made of the best wrought iron of sufficient weight to be perfectly rigid, and being accurately fitted to the gates and ring, the gates always shut perfectly tight.

The follower-box contains four wood followers which are placed with end of wood to the shaft and backed with iron plates, and held and adjusted to the shaft by set-screws, against the iron plate backing. Sufficient space is allowed between the box and the coupling to admit the follower-blocks.

The lower end of the pinion or gate-shaft is carried in a step on the bottom plate of the case, having a bearing or steady-rest just below the pinion, thus preventing the shaft from springing and insuring the pinion and segment being always in gear.

To the upper end of the pinion shaft, a face coupling is fitted, by which connection is made to the upper gate-shaft. We furnish the hand-wheel, spur-wheel and pinion, all fitted to short shafts.

The lower plate of the case is faced off on its under side to receive the cylinder, which are bolted together with cap-screws. The cylinder flange is faced off on both sides at right angles to the wheel-shaft, and rests upon the cant on the floor of the flume, and if the cant is level, the case will set perfectly plumb. The cylinder is conical in form, and has palms on the inside near the bottom for receiving the

bridgetree, which is securely held by bolts passing through the palms.

The hub of the bridgetree is bored to receive the step-thimble which is turned to fit the hub accurately, thereby bringing the step exactly central, and requiring no lateral adjustment. The step is made of lignum vitæ and is adjusted vertically by means of a large square-threaded screw in bottom of the bridgetree hub; when the wheels are installed under high heads an auxiliary or safety step is used on the dome of the wheel, taking the place of the follower-box. By the use of the safety step, the burning out of steps is reduced to a minimum. The wheel itself is relieved of all hydrostatic pressure due the head by having holes cored through the hub, parallel to the bore of the wheel, thus permitting water which would otherwise rest on the top of the runner to discharge itself, and the steps are therefore relieved of all undue weight or pressure, save only the weight of the wheel, shaft and driving gear. Fig. 5 shows the wheel and case complete, equipped with safety step on dome. All castings entering into the construction of our wheels are made from a mixture of the best charcoal iron, insuring castings of the highest tensile strength.

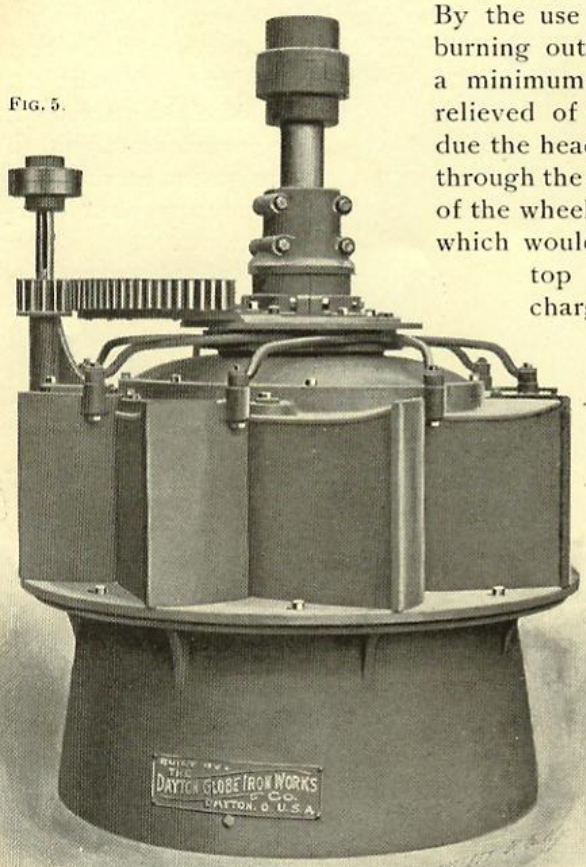
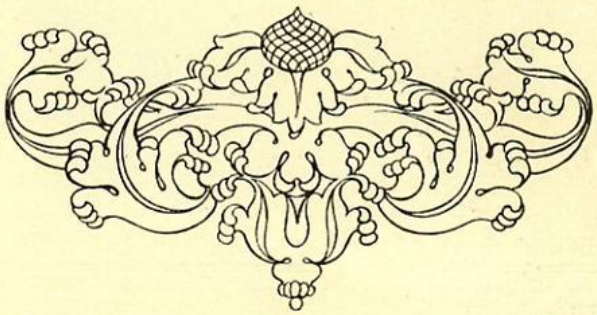


FIG. 5.

The machine-work is done by gauge or template, so that any part can be duplicated. The work of construction is so divided

that one class of work is always performed by the same mechanics, who are therefore specialists in their class.

The runner, case and cylinder with its bridgetree are each turned and bored at one operation, so that in assembling, the wheel comes exactly central in the case and cylinder, and the flanges of the case and cylinder being faced off square with the bore, when the cant on which they rest is level, the wheel will be plumb. The case having first been carefully fitted up with its gates and gate-operating mechanism, the assembling or setting up is then complete and the wheel perfect in every detail, ready for shipment.



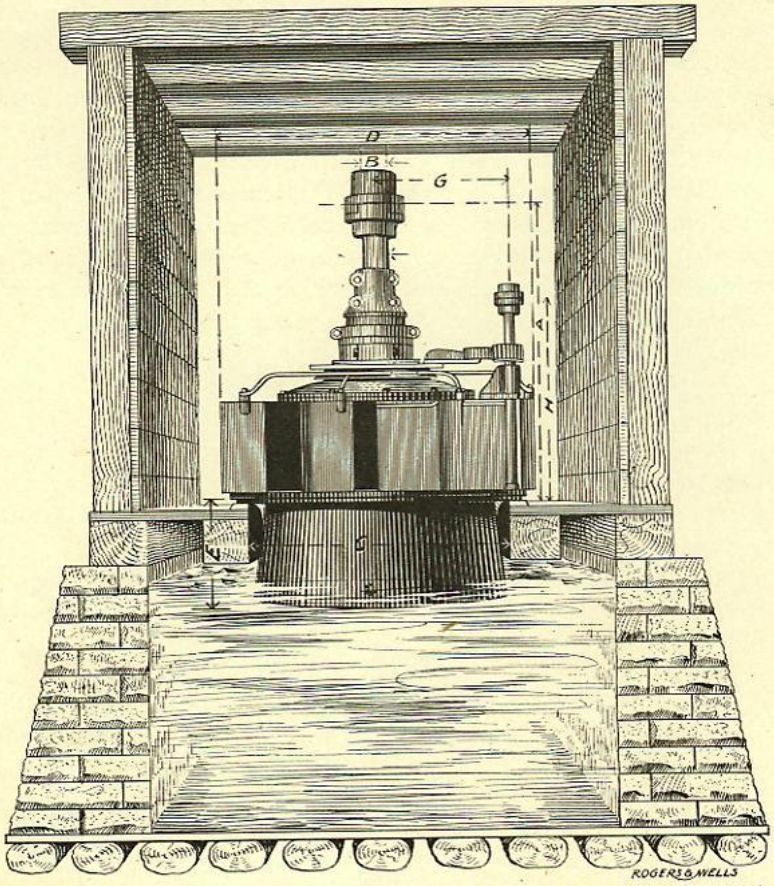


Table of Dimensions of the Special New American Turbines

Diameter of wheel, inches	Length of shaft from deck to center of coupling, inches **A**	Bore of coupling, inches **B**	Diameter of hole for cylinder of wheel, inches **C**	Extreme diameter over all with gates open, inches **D**	Length of cylinder from face of deck to lower end, inches **E**	Distance from center of water wheel shaft to center of gate shaft, inches **G**	Length of gate shaft from deck to center of coupling, inches **H**
10	24	1 7/16	19	26	6 1/4	10 1/8	15
13	32 7/16	2 7/16	24 1/8	28 3/8	10 3/8	11	20
16	36	2 7/16	28 3/4	38	12	14 13/16	22
19	38 7/8	2 11/16	32 1/4	42	12 3/8	16 1/4	26 1/4
22	40 3/4	2 11/16	36 7/8	50 7/8	16 3/4	19 7/16	29 1/2
25	47	3 7/16	40 1/4	51	17 1/2	18 7/8	32 1/4
27 1/2	50	3 15/16	43 7/8	57	19 1/2	22 1/8	33
30	50 1/2	3 15/16	47	57 3/4	20 5/16	22 1/2	34
33	56 1/2	4 7/16	50 3/4	65 3/4	21	26 1/2	42
36	60	4 15/16	54 1/2	71	24	28 1/2	43 1/2
39	63 7/8	4 15/16	57 3/4	75 1/4	25 1/2	30 3/8	44
42	60	4 15/16	59 1/8	79	23 3/4	32 1/8	44 5/8
45	61 1/8	4 15/16	63 3/8	81 3/4	23 7/8	32 1 1/16	41 9/16
48	66	5 7/16	66 3/4	86 1/2	25	35 1/4	41
51	75 1/2	6	71 3/4	92 1/4	27	36 7/8	52 3/4
54	74 1/4	6 1/2	77 5/8	94 1/8	29 5/8	38 5/8	57
57	79 1/4	7	80	100 1/2	31 5/8	42 1/8	57
60	76 3/4	7	84	102 1/2	32 3/4	43	58

Cylinder Gate New American

AS stated heretofore, we maintain and have proven that the American form of gate, with its graduated chutes, gives the best application of water to a turbine. We are, however, not always able to convert purchasers to our belief, and therefore, with a view to meeting all demands and supplying those who may be prejudiced in favor of cylinder gates with stationary guides, we have made a full line of cylinder gate cases, and are prepared to furnish the New American wheel with either style of gate as preferred.

The cylinder gate has its virtues, which, to its advocates, need not be dilated upon here. Where our unbiased judgment and advice are requested, we unqualifiedly recommend the American gate, on account of the high part-gate results it obtains, its easy-working gate mechanism, and its freedom from clogging with ice or floating debris.

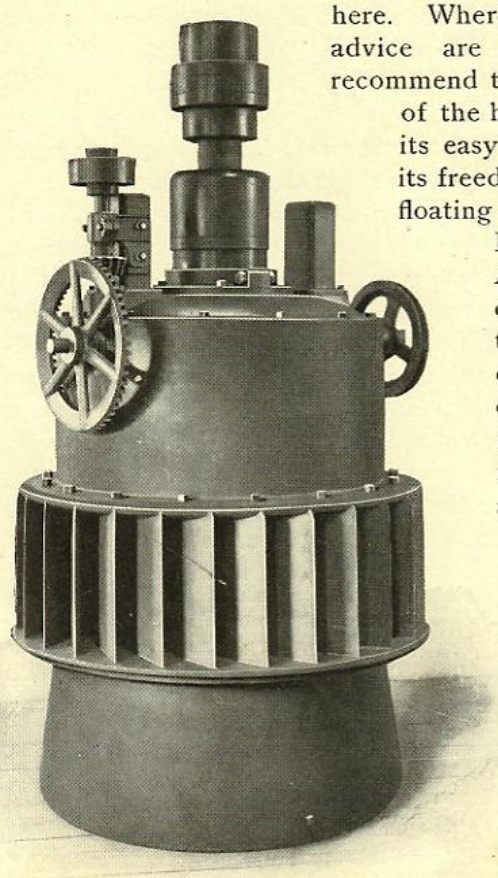


FIG. 6.
CYLINDER GATE WHEEL.

In deciding to furnish the New American with cylinder gate case it has not been our intention to build a mere excuse for a wheel, but having carefully studied the construction, we have overcome the many faults of other builders, and can say, as of the New American with graduated chute case, that our cylinder gate is the best wheel of its type on the market.

Fig. 6 shows a vertical wheel complete, and in Figs. 20 to 23, pages 58 and 59 are shown the parts in detail of a pair of horizontal wheels. These cuts show the construction so plainly that explanation is scarcely necessary.

It will be noticed that the hoisting rig is contained entirely within the dome of the case, where no foreign objects can interfere with its operation.

The racks are attached rigidly to the ring or cylinder so that it cannot wabble in being raised or lowered. The cylinder is further provided with three brass strips, V-shaped, which in connection with the corresponding grooves in the case, act as guides and sliding ways for the cylinder. When worn these strips can be replaced with little expense or loss of time.

The racks are supported in their travel by roller bearings situated under the crown-plate. The pinion-shaft runs in babbitted boxes, and is fitted at one end with a bevel gear, and at the other with sheave-wheel for carrying the balance-weight. The gate-shaft is carried in a step-box in the dome, and supported above the bevel pinion by a steady-rest.

In other respects the description already given of the New American wheel may be added here.

Our line of wheels is very complete in sizes, embracing both right and left-hand patterns, and ranging in diameter from ten inches to sixty inches, with intermediate sizes for every three inches additional diameter. These are our standard patterns and enable a purchaser to obtain almost any desired power and speed for any head.

On pages 12 and 15 are shown two cuts representing the New American, both styles of gate, as they set on the floor of an ordinary timber flume, together with tables giving the principal dimensions and lengths as indicated by letters. It will be seen that on the floor of the flume there is a cant which is spiked on the face of the floor, which is then planed level to receive the wheel case. The lower flange of the case is turned off on the under side, and is at right angles to the line of shaft; consequently when the cant is level and true the shaft will be plumb. When iron draft-tubes are used, there is a cast flange on the end of the tube, which rests on the cant, and the wheel case rests on the flange of draft-tube. This is faced on both sides, consequently rests fair on the cant and forms a true level surface for wheel-case.

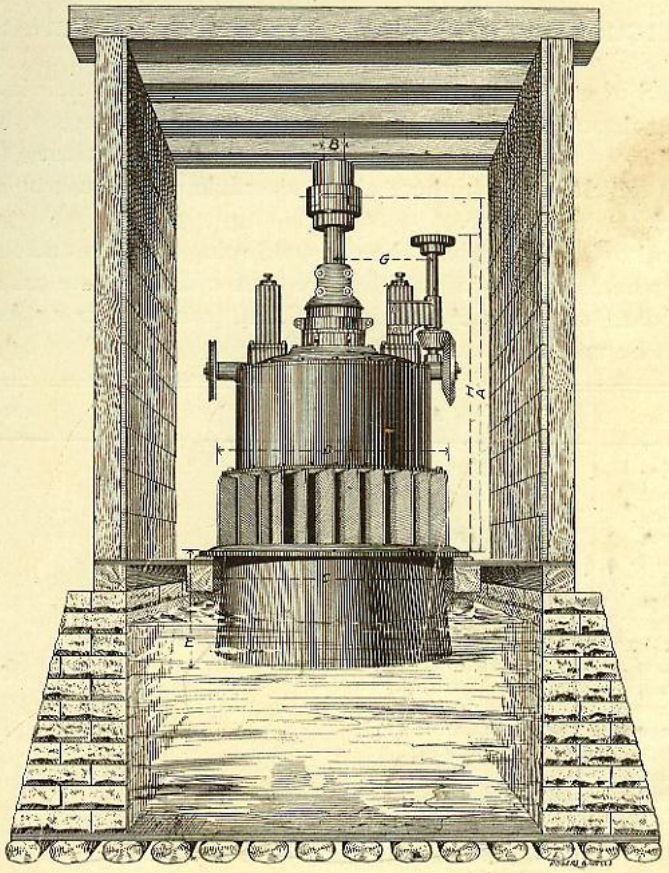


Table of Dimensions of the Cylinder Gate New American Turbine

Diameter of wheel, inches	Length of shaft from deck to center of coupling, inches A	Bore of coupling, inches B	Diameter of hole for cylinder of wheel, inches C	Extreme diameter of guides, inches D	Length of cylinder from face to lower end, inches E	Distance from main shaft to gate shaft, inches G	Height of gate shaft from deck, inches H
10	36	1 7/16	19	18½	6¼	7½	30
13	38	2 7/16	24⅛	22¾	10⅜	9⅛	33
16	42	2 7/16	28¾	27	12	10¾	36
19	51¾	2 11/16	32¾	31¼	12⅜	12⅜	38
22	57	2 11/16	36⅞	35½	16¾	14	40
25	63	3 7/16	40¼	39¾	17½	15⅝	44
27½	67	3 15/16	43⅞	42½	19½	17¼	48
30	72	3 15/16	47	46¾	20 5/16	18⅞	52
33	85	4 15/16	50¾	50½	21	20¾	57
36	87	4 15/16	54½	55	24	22⅜	61
39	89	4 15/16	57¾	59¼	25½	24	65
42	90	4 15/16	59⅛	65½	23¾	25¼	70
45	93	4 15/16	63⅜	67½	23⅞	26⅞	74
48	96	5 7/16	66¾	72	25	28¾	78
51	100	6	71¾	76	27	30⅜	82
54	104	6½	77⅝	80¼	29⅝	32	84
57	108	7	80	84	31⅝	33¼	86
60	111	7	84	89	32¾	34⅞	88

Price List of New American Turbine

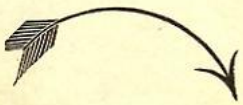
USERS of water as a motive power will find it to their interest to purchase well-made turbines of high efficiency, rather than cheaply made wheels of low efficiency at any price. The New American develops the highest average efficiency from whole to half water of any wheel made.

The following table gives the sizes, shipping weights and list prices of these wheels, both graduated chute and cylinder gate cases, delivered on board cars Dayton, Ohio, U. S. A., from which a liberal discount will be made for cash:

Size of Wheel	Material	Price	Shipping Weight
6 inches	Made of brass	$200.00	
8 inches	Runner and gates brass	235.00	
10 inches	Runner and gates brass	275.00	750
13 inches	Made of iron	335.00	1,000
16 inches	Made of iron	375.00	1,550
19 inches	Made of iron	435.00	1,800
22 inches	Made of iron	500.00	2,600
25 inches	Made of iron	560.00	3,200
27½ inches	Made of iron	615.00	4,000
30 inches	Made of iron	720.00	4,800
33 inches	Made of iron	815.00	6,000
36 inches	Made of iron	935.00	7,500
39 inches	Made of iron	1,050.00	8,500
42 inches	Made of iron	1,135.00	9,300
45 inches	Made of iron	1,280.00	10,000
48 inches	Made of iron	1,435.00	11,500
51 inches	Made of iron	1,680.00	14,600
54 inches	Made of iron	1,920.00	17,500
57 inches	Made of iron	2,150.00	20,000
60 inches	Made of iron	2,500.00	22,500

Above prices are for wheels complete, with couplings as shown in Fig. 5 and Fig. 6. There is also included one spur-wheel and pinion, one hand-wheel, one ratchet-wheel, each fitted and keyed on short pieces of shaft with turned bearings, to which purchasers can weld any additional length to suit required condition.

In ordering wheels, state whether they are to run with the sun or against the sun, as indicated by arrows.



WITH THE SUN, OR RIGHT HAND

AGAINST THE SUN, OR LEFT HAND.

Notice to Correspondents

PARTIES writing to us for information in regard to our turbines will please be particular to state :

If vertical :

1. The head under which the wheel is to run, *i. e.*, the vertical distance from the surface of the head-water to the surface of the tail-water when at rest.
2. The quantity of water which the stream will supply, and whether variable or constant.
3. The number of horse-power required.
4. The kind and amount of machinery to be driven.
5. Whether the wheel is to run right-hand, *i. e.*, with the sun, or left-hand, *i. e.*, against the sun.
6. The speed at which the line-shaft is to run.

If horizontal, in addition to the above :

7. The distance from the level of tail-water to center of water-wheel shaft.
8. The direction the shaft is to revolve.
9. The manner in which the power is to be taken off.
10. If possible, a sketch showing the location and conditions.

Conditions of Guarantee

WE guarantee our wheels to develop the power represented in our tables, to be perfect in material and workmanship, and to operate satisfactorily when set in accordance with our instructions. We will not be responsible for failure in their performance, in consequence of the wheels not being properly set and geared, or the flumes, wheel-pit and water-courses not being made in accordance with our instructions, or on account of misrepresentation as to the head or the quantity of water.

No trouble will occur when our directions are followed.

THE DAYTON GLOBE IRON WORKS CO.

Tables for New American Turbine

ON the following pages we give the tables of the horse-power of the New American turbine under heads from three feet to fifty feet. These tables have been carefully computed from actual tests made on our wheels at the Holyoke testing flume, and we guarantee them correct as to power, speed and amount of water used under the heads given. The tests themselves, together with minute explanation of the manner of testing and how the tables are deduced therefrom, are fully set forth in the ensuing pages, so that anyone can satisfy himself as to their correctness. An actual dynamometric test is the only correct basis from which the power of a wheel can be tabled, as we shall show further on, and a table without such test as its basis is not worth the paper it is printed on.

The horse-power in the tables is the actual power developed, the revolutions the proper working speed in revolutions per minute, and the cubic feet the actual quantity of water discharged in cubic feet per minute.

In addition to our regular line of wheels we have tabled the six-inch and eight-inch wheels, which are wheels of smaller proportionate discharge, also a number of wheels of special design which have been made to meet special requirements of speed or power.

In this connection we take occasion to say that we are specially qualified by our long experience to build wheels to meet special conditions.

The requirements in the development of water-power, especially for electric power, are daily becoming more varied and unusual, making it necessary to build wheels especially for the purpose. This we can do with certainty and reliability and guarantee results.

Table of the New American Turbine

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	22-inch wheel			25-inch wheel			27½-inch wheel			30-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	101	964	4.3	89	1208	5.4	81	1562	7.0	75	1890	8.4
4	117	1113	6.7	103	1395	8.4	93	1805	10.9	85	2183	13.1
5	130	1244	9.3	115	1560	11.8	104	2017	15.2	97	2439	18.3
6	143	1363	12.3	126	1708	15.4	114	2209	20.0	104	2674	24.1
7	155	1473	15.5	136	1845	19.4	123	2388	25.2	113	2888	30.5
8	165	1575	19.0	146	1973	23.7	132	2552	30.8	122	3086	37.3
9	175	1669	22.6	154	2093	28.4	140	2707	36.8	128	3275	44.5
10	184	1760	26.5	162	2206	33.3	148	2853	43.1	135	3443	51.9
11	193	1846	30.6	170	2314	38.5	153	2992	49.7	142	3622	60.2
12	202	1928	34.9	178	2417	43.8	160	3126	56.6	148	3780	68.5
13	211	2007	39.3	186	2516	49.4	167	3252	63.9	154	3934	77.2
14	219	2082	44.0	193	2611	55.2	174	3376	71.4	161	4085	86.4
15	227	2157	48.7	199	2702	61.2	179	3496	79.2	166	4230	95.8
16	234	2227	53.7	206	2790	67.5	186	3609	87.3	171	4367	105.4
17	241	2295	58.8	212	2876	73.9	192	3722	95.6	176	4502	115.6
18	248	2362	64.2	218	2959	80.5	197	3830	104.1	182	4634	126
19	254	2426	69.5	224	3041	87.3	203	3934	112.9	187	4759	136.6
20	261	2489	75.1	230	3120	94.3	208	4036	121.9	193	4878	147.3
21	268	2550	80.8	236	3196	101.3	214	4135	131.2	196	5003	158.6
22	274	2611	86.7	241	3272	108.8	219	4232	140.6	200	5120	170.2
23	280	2670	93 8	247	3346	116.3	223	4327	150.4	206	5235	181.9
24	286	2727	98.7	252	3417	123.8	227	4421	160.2	210	5348	193.7
25	292	2783	105.1	257	3489	131.7	233	4512	170.4	214	5459	206.2
26	298	2839	111.4	262	3557	139.7	238	4601	180.7	218	5567	218.6
27	304	2892	117.9	267	3626	147.9	242	4678	191.3	223	5676	231.5
28	310	2946	124.5	272	3691	156.	247	4775	202.0	227	5775	244.3
29	315	2998	131.2	277	3757	164.6	251	4859	212.9	231	5880	257.6
30	321	3049	138.2	282	3822	173.3	255	4943	224.1	234	5980	271.
31	326	3100	145.1	287	3884	182.	259	5024	235.4	238	6080	284.7
32	331	3150	152.2	292	3946	190.8	263	5105	246.8	242	6177	298.6
33	336	3198	159.4	296	4007	199.8	267	5174	258.6	246	6272	312.8
34	341	3246	166.7	300	4068	209.	271	5263	270.3	250	6369	327.2
35	346	3293	174.0	304	4128	218.3	275	5340	282.5	253	6463	341.8
36	351	3330	181.6	308	4187	227.7	279	5415	294.6	256	6550	356.3
37	356	3386	189.2	313	4244	237.3	284	5489	306.9	260	6643	371.4
38	361	3431	196.9	317	4301	246 9	288	5563	319.4	265	6731	386.5
39	365	3477	204.8	321	4356	256.9	291	5635	332.1	268	6820	401.8
40	369	3521	212.7	324	4412	266.6	295	5706	344.9	271	6904	417.3
41	373	3564	220.	328	4466	276.4	299	5776	357.8	273	6972	431.9
42	377	3607	228.1	332	4521	286.6	303	5847	371.	276	7056	447.9
43	381	3650	236.3	336	4575	296.9	307	5916	384.3	279	7139	463.9
44	386	3692	244 6	339	4628	307.3	310	5985	397.8	283	7222	480.2
45	390	3734	253.	343	4680	317.9	314	6052	411.4	286	7304	496.7
46	394	3774	261.4	347	4731	328.5	317	6119	425.2	289	7385	513.3
47	398	3815	270.	351	4782	339.3	320	6185	439.2	292	7464	530.1
48	403	3856	278.7	354	4833	350.2	324	6251	453.3	295	7543	547.1
49	407	3896	287.4	358	4883	361.2	327	6315	467.5	298	7621	564.3
50	411	3936	296.3	362	4932	372.3	331	6379	481.9	301	7699	581.7

Table of the New American Turbine

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	10-inch wheel			13-inch wheel			16-inch wheel			19-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	212	203	.9	171	308	1.4	140	499	2.2	117	737	3.3
4	245	233	1.4	197	356	2.1	161	577	3.5	135	851	4.1
5	274	262	1.9	221	398	3.0	181	643	4.9	151	950	7.1
6	300	287	2.6	242	435	3.9	197	706	6.3	166	1043	9.5
7	324	309	3.2	261	470	5.0	213	763	8.1	179	1125	11.9
8	346	330	4.	279	503	6.0	227	815	10.1	192	1204	14.5
9	368	351	4.7	297	533	7.2	243	865	11.8	204	1276	17.3
10	388	369	5.7	313	563	8.5	255	911	13.8	214	1345	20.1
11	406	387	6.4	328	589	10.0	267	956	15.8	225	1411	23.5
12	424	404	7.4	342	616	11.2	279	998	18.0	235	1475	26.7
13	441	421	8.2	356	641	12.6	290	1039	20.4	245	1534	30.1
14	458	438	9.2	370	665	14.1	301	1080	22.8	253	1591	33.6
15	474	453	10.2	382	689	15.5	311	1118	25.7	262	1649	37.3
16	490	467	11.3	397	711	17.2	321	1153	28.8	271	1702	41.1
17	505	481	12.3	407	734	18.7	332	1189	30.4	279	1755	45.0
18	520	495	13.5	419	755	20.5	342	1224	33.6	288	1806	49.1
19	534	509	14.7	431	776	22.2	352	1257	36.0	295	1855	53.2
20	548	523	16.1	442	795	24.0	361	1285	39.3	302	1901	57.4
21	561	536	17.	453	815	25.0	371	1321	41.9	310	1950	61.8
22	574	548	18.2	464	834	27.7	379	1353	44.3	317	1995	66.3
23	587	561	19.4	474	853	29.6	387	1383	48.0	324	2041	70.9
24	600	572	20.7	483	871	31.7	395	1412	51.1	332	2086	75.6
25	612	585	22.1	495	889	33.6	402	1441	54.4	339	2128	80.3
26	624	596	23.3	504	907	35.5	410	1471	57.7	346	2170	85.2
27	636	607	24.9	513	924	37.6	418	1499	61.0	353	2212	90.3
28	648	620	26.3	523	940	39.7	426	1527	64.5	359	2251	95.2
29	659	630	27.5	531	958	42.0	434	1553	68.0	365	2291	100.3
30	670	641	29.1	541	974	44.1	440	1580	71.6	372	2334	105.7
31	681	651	30.5	550	990	46.3	447	1605	75.1	378	2370	111.0
32	692	662	32.	559	1005	48.5	454	1631	80.7	384	2408	116.3
33	703	672	33.4	567	1021	50.9	461	1656	83.8	391	2445	121.9
34	714	681	35.	576	1036	53.2	468	1681	86.3	397	2482	127.4
35	725	691	36.5	584	1051	55.5	476	1707	90.2	402	2518	133.1
36	736	701	38.2	593	1067	58.1	485	1730	94.7	407	2553	138.8
37	746	711	39.7	601	1081	60.4	491	1754	98.0	413	2590	144.7
38	756	721	41.4	609	1096	62.8	498	1778	102.1	418	2623	150.6
39	766	730	43.1	616	1110	65.3	504	1801	106.0	423	2658	156.6
40	776	740	44.8	625	1124	67.9	510	1821	110.2	428	2690	161.7
41	786	749	46.3	633	1140	70.5	516	1845	114.5	433	2723	166.8
42	795	757	48.1	641	1154	73.1	522	1867	118.7	438	2756	173.
43	805	767	49.8	649	1168	75.8	528	1889	123.	443	2789	179.2
44	814	775	51.5	656	1181	78.4	535	1911	127.4	449	2821	185.5
45	823	784	53.3	664	1194	81.1	541	1932	131.7	454	2853	191.9
46	832	793	55.1	671	1207	83.8	547	1954	136.1	459	2885	198.3
47	841	802	57.	678	1220	86.6	552	1975	140.6	464	2916	204.8
48	850	810	58.8	685	1233	89.4	558	1996	145.1	469	2947	211.3
49	859	819	60.6	692	1246	92.2	564	2017	149 7	473	2977	218.
50	868	827	62.4	700	1259	95.	570	2037	154.3	478	3008	224.7

Table of the New American Turbine

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	33-inch wheel			36-inch wheel			39-inch wheel			42-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	68	2279	10.3	62	2853	12.8	57	3098	14.0	54	3467	16.0
4	78	2629	15.8	71	3296	19.7	65	3578	21.6	62	4003	24.1
5	87	2941	22.2	80	3682	27.8	73	4001	30.2	68	4475	33.7
6	95	3220	29.1	87	4039	36.6	80	4382	39.7	75	4901	44.4
7	104	3480	36.8	95	4361	46.1	87	4726	50.0	81	5296	56.
8	110	3721	45.0	101	4660	56.3	92	5063	61.1	86	5670	68.4
9	117	3946	53.4	107	4945	67.2	98	5362	73.0	92	6006	81.7
10	124	4159	62.8	113	5211	78.7	104	5658	85.4	97	6329	95.6
11	129	4362	72.4	118	5465	90.7	108	5935	98.6	101	6639	110.3
12	135	4555	82.5	123	5709	103.5	113	6197	112.3	106	6935	125.6
13	140	4744	93.1	128	5943	116.5	117	6449	126.7	110	7216	141.7
14	146	4917	104.0	133	6168	130.3	122	6696	141.6	114	7494	158.5
15	151	5094	115.5	138	6384	144.6	126	6932	157.1	119	7753	177.3
16	156	5260	126.7	143	6593	159.5	131	7156	173.0	123	8007	193.6
17	161	5422	139.2	147	6796	174.5	135	7379	190.3	126	8255	210.0
18	166	5583	151.8	151	6996	190.2	139	7593	206.5	130	8493	231.0
19	170	5736	164.6	155	7185	206.2	143	7800	224.0	132	8726	250.5
20	175	5881	177.6	160	7373	222.8	146	8001	241.5	137	8954	270.4
21	179	6028	191.2	164	7552	239.7	150	8195	260.2	141	9174	291.1
22	184	6165	204.8	168	7730	256.8	154	8392	279.0	144	9388	312.1
23	187	6307	219.1	171	7904	274.6	157	8582	298.3	147	9601	333.7
24	191	6441	233.3	174	8076	293.6	160	8767	317.8	150	9807	355.6
25	196	6579	248.4	179	8242	311.3	164	8948	338.0	153	10009	378.2
26	200	6708	263.5	183	8405	330.2	168	9124	358.4	155	10206	401.1
27	204	6836	278.8	186	8565	349.4	171	9297	379.3	159	10402	424.4
28	207	6961	294.5	189	8723	368.9	173	9452	400.5	162	10593	448.1
29	210	7078	310.1	192	8877	389.9	176	9634	422.2	165	10779	472.4
30	214	7204	326.4	195	9028	409.2	179	9803	448.1	168	10966	497.2
31	217	7322	342.9	198	9177	429.7	182	9963	466.7	170	11145	522.1
32	221	7441	359.7	202	9326	450.9	185	10126	489.4	173	11340	548.3
33	224	7560	376.8	205	9468	472.1	188	10280	512.6	175	11500	573.4
34	228	7670	394.0	208	9614	493.8	191	10436	536.2	179	11674	599.7
35	231	7779	411.4	211	9753	515.6	194	10591	560.1	181	11848	626.6
36	235	7893	429.3	214	9890	538.	196	10737	584.0	184	12012	653.2
37	238	8004	447.4	217	10026	560.4	199	10885	608.6	187	12176	680.9
38	242	8111	465.7	221	10161	583 5	202	11032	633.5	189	12340	708.6
39	244	8216	484.1	223	10294	606.6	204	11175	658.2	191	12501	736.7
40	247	8318	502.8	226	10425	629.1	207	11316	684.1	193	12659	765.3
41	251	8421	521.7	228	10551	653.7	210	11456	709.8	196	12815	793.8
42	254	8524	541.	231	10680	677.7	213	11595	735.9	198	12970	823.1
43	257	8624	560.4	234	10806	702.2	215	11732	762.3	201	13124	852.7
44	260	8724	580.	237	10930	726.7	218	11868	789.1	203	13276	882.6
45	263	8822	600.	239	11054	751.8	220	12002	816.1	205	13426	912.9
46	266	8920	620.1	242	11176	776.9	223	12135	843.5	208	13574	943.5
47	268	9017	640.4	245	11297	802.3	225	12266	871.1	210	13721	974.4
48	271	9112	660.9	247	11416	828.1	228	12396	899.1	212	13866	1005.7
49	274	9206	681.7	250	11535	854.1	230	12524	927.3	214	14010	1037.2
50	277	9300	702.7	252	11652	880.4	232	12652	955.9	216	14152	1069.2

Table of the New American Turbine

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	45-inch wheel			48-inch wheel			51-inch wheel			54-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	50	4161	18.8	47	4788	21.6	44	5113	23.1	41	6019	27.2
4	57	4806	29.	54	5530	33.1	51	5905	35.7	48	6952	42.
5	64	5373	40.5	60	6177	46.6	57	6602	49.9	54	7772	58.7
6	70	5886	53.3	65	6776	61.6	62	7231	65.6	58	8512	77.2
7	76	6359	67.2	71	7317	77.2	67	7811	82.6	64	9195	97.3
8	81	6797	82.	76	7819	94.4	71	8351	101.	68	9830	118.9
9	86	7210	98.	81	8296	112.8	77	8857	118.0	72	10427	138.9
10	90	7599	114.8	85	8743	132.1	80	9344	141.2	75	11000	166.2
11	95	7971	132.3	88	9169	152.4	84	9792	162.9	79	11528	191.7
12	99	8323	150.8	92	9577	173.6	88	10228	185.6	82	12040	218.4
13	103	8665	170.2	97	9972	195.3	91	10645	209.4	85	12531	246.4
14	107	8992	190.1	101	10348	218.7	95	11047	234.0	89	13005	275.4
15	111	9308	210.8	104	10711	242.7	98	11435	259.4	92	13461	305.3
16	114	9725	232.4	107	11061	267.4	102	11809	285.8	95	13902	336.5
17	117	9908	254.3	111	11403	292.9	104	12173	313.	98	14329	368.5
18	121	10196	277.2	113	11737	319.	107	12526	341.	101	14746	401.4
19	125	10475	300.	117	12054	346.	110	12869	369.9	103	15150	435.4
20	128	10747	324.6	120	12369	373.8	113	13353	402.	106	15543	470.2
21	131	11012	349.4	123	12670	402.1	117	13530	429.8	109	15928	506.
22	134	11271	374.6	126	12969	431.	119	13848	460.9	111	16302	542.5
23	137	11525	400.5	128	13261	460.8	122	14160	492.7	114	16669	580.
24	140	11774	426.9	131	13548	492.4	124	14465	525.1	116	17028	618.1
25	143	12016	453.8	134	13825	510.2	127	14762	558.3	119	17378	657.2
26	146	12253	481.3	136	14101	553.9	129	15054	592.	121	17722	696.9
27	149	12488	510.3	139	14370	586.2	131	15341	626.6	123	18060	737.6
28	152	12717	538.	142	14635	619.	134	15623	661.8	126	18391	779.
29	154	12941	567.	144	14893	654.1	137	15899	697.5	128	18717	821.2
30	157	13163	596.6	147	15147	686.6	139	16170	733.9	130	19036	863.9
31	159	13381	626.8	149	15397	721.	141	16438	770.8	132	19351	907.4
32	162	13595	657.4	151	15648	756.3	144	16702	808.4	134	19661	951.6
33	164	13805	688.3	153	15885	792.	146	16961	846.7	136	19967	996.7
34	167	14013	719.8	156	16129	828.4	148	17215	885.4	138	20266	1042.3
35	169	14218	751.9	159	16363	865.2	150	17466	924.8	f40	20562	1088.7
36	172	14420	784.2	161	16592	902.6	152	17714	964.6	142	20853	1135.6
37	174	14618	817.2	163	16821	940.3	155	17959	1005.2	144	21142	1183.4
38	176	14815	850.6	165	17047	978.9	157	18200	1046.2	146	21426	1231.6
39	178	15009	884.4	167	17271	1017.8	158	18438	1087.8	148	21706	1280.6
40	180	15199	918.6	169	17491	1055.4	160	18673	1129.9	150	21983	1330.1
41	182	15387	953.2	172	17703	1096.7	162	18920	1172.2	151	22273	1380.
42	184	15573	988.4	174	17918	1137.1	164	19150	1215.4	153	22543	1430.7
43	186	15758	1023.8	176	18130	1178.	165	19376	1259.	155	22810	1482.1
44	188	15940	1059.7	178	18339	1219.3	167	19600	1303.2	157	23074	1534.1
45	191	16120	1096.1	180	18546	1261.1	169	19821	1347.9	159	23334	1586.8
46	193	16298	1132.9	182	18752	1303.4	171	20040	1393.	160	23592	1640.
47	195	16474	1170.	184	18950	1346.1	173	20258	1438.7	162	23848	1693.7
48	197	16648	1207.5	186	19155	1389.3	175	20472	1485.	164	24100	1748.
49	199	16821	1245.4	188	19353	1432.9	177	20684	1531.5	166	24350	1762.
50	201	16992	1283.8	190	19555	1477.	178	20894	1578.7	167	24600	1858.5

Table of the New American Turbine

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	57-inch wheel			60-inch wheel			72-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	39	6586	29.8	38	7660	35.3	32	10935	49.5
4	45	7607	45.9	44	8845	53.4	37	12627	76.3
5	51	8503	64.2	48	9883	74.6	42	14117	106.7
6	55	9312	84.3	52	10837	98.1	46	15464	140.2
7	60	10064	106.3	57	11702	123.7	50	16703	176.7
8	64	10755	130	62	12508	151.2	53	17857	215.9
9	68	11419	155.1	67	13268	180.3	56	18941	257.6
10	71	12028	181.6	70	13986	211.3	59	19965	301.6
11	75	12615	209.7	73	14669	243.8	62	20940	348.
12	78	13173	238.6	77	15320	282.5	65	21870	396.6
13	82	13709	269.3	80	15949	313.1	68	22763	447.2
14	85	14233	301.	82	16550	350.	71	23623	499.7
15	88	14798	333.9	85	17129	388.2	73	24452	554.3
16	91	15214	367.7	88	17692	427.5	75	25254	610.6
17	94	15683	402.7	90	18237	468.4	77	26030	668.7
18	96	16140	439.	92	18767	510.4	80	26790	728.6
19	98	16580	475.8	95	19280	553.5	82	27520	790.1
20	101	17008	513 9	100	19767	597.2	84	28234	853.3
21	104	17428	552.9	102	20268	643.1	86	28932	918.1
22	106	17866	592.9	104	20743	689.5	88	29613	984.5
23	109	18241	633.9	106	21211	737.1	90	30280	1052.4
24	111	18635	675.	108	21674	785.9	92	30930	1121.7
25	113	19017	718.5	110	22115	835.4	94	31570	1192.5
26	115	19392	760.9	112	22551	885.9	96	32193	1264.8
27	118	19764	806.3	114	22980	937.6	98	32806	1338.5
28	120	20124	850.7	116	23406	990.2	100	33408	1413.5
29	122	20614	897.5	119	23820	1043.7	101	34000	1490.
30	124	20835	944.5	121	24227	1098.2	103	34580	1567.6
31	126	21177	992.	122	24624	1153.4	105	35152	1646.7
32	128	21511	1040.3	124	25016	1209.1	106	35714	1727.
33	130	21850	1089.6	126	25407	1266.8	108	36270	1808.6
34	132	22182	1139.6	128	25793	1325.2	110	36814	1891.4
35	135	22509	1190.5	130	26169	1390.1	112	37350	1975.5
36	136	22838	1241.6	131	26537	1443.3	113	37880	2061.
37	138	23136	1293.6	134	26902	1504.1	115	38400	2147.
38	140	23450	1346.5	136	27266	1565.6	116	38920	2235.
39	142	23739	1399.8	138	27625	1628.	118	39430	2323.6
40	144	24056	1453.8	139	27970	1690.7	119	39930	2413.6
41	145	24354	1508.8	141	28319	1754.5	121	40426	2504.6
42	147	24650	1564.4	143	28663	1819.	122	40916	2597.
43	149	24940	1620.6	145	29002	1884.5	124	41400	2690.
44	150	25230	1677.5	146	29337	1950.6	125	41880	2784.5
45	152	25515	1735.	148	29670	2017.5	126	42350	2880.
46	154	25797	1793.1	150	29997	2085.1	128	42820	2977.
47	155	26076	1852.	151	30321	2153.5	129	43283	3074.
48	157	26352	1911.4	153	30642	2222.5	131	43740	3173.
49	158	26625	1971.4	155	30959	2292.	132	44194	3272.
50	159	26895	2032.	156	31274	2363.	133	44640	3373.

Table of the New American Turbine (Reduced Discharge)

UNDER HEADS FROM 3 TO 50 FEET

Head in feet	6-inch wheel			8-inch wheel			36-inch wheel			45-inch wheel		
	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power	Revolutions per minute	Cubic feet per minute	Horse power
3	353	58	.3	266	98	.4	62	1111	5.	50	2084	9.4
4	409	67	.4	307	114	.7	71	1283	7.7	57	2406	14.6
5	457	75	.6	343	127	1.	80	1434	10.8	64	2690	20.4
6	500	83	.7	376	139	1.3	87	1571	14 2	70	2946	26.6
7	540	89	.9	406	150	1.6	95	1697	17 9	76	3182	33.6
8	579	95	1.2	434	161	2.	101	1814	21 9	81	3402	41.
9	613	101	1.4	460	170	2.3	107	1924	26.1	86	3610	49.
10	646	106	1.6	486	180	2.7	113	2028	30.6	90	3804	57.4
11	677	111	1.8	509	188	3.1	118	2128	35.3	95	3990	66.4
12	706	116	2.1	532	197	3.6	123	2222	40.3	99	4168	75.6
13	736	121	2.4	553	205	4.	128	2313	45.4	103	4338	85.2
14	764	126	2.7	574	212	4.5	133	2400	50.7	107	4502	95.2
15	792	130	2.9	595	220	5.	138	2484	56 3	111	4660	105 6
16	818	134	3.2	614	227	5.5	143	2566	62.	114	4812	116.4
17	842	139	3.6	633	234	6.	147	2645	67.9	117	4960	127.4
18	867	143	3.9	651	241	6.6	151	2722	74.	121	5104	138.8
19	891	147	4.2	669	248	7.1	155	2796	80.2	125	5244	150.6
20	914	150	4.5	686	254	7.7	160	2869	86.7	128	5380	162.6
21	936	154	4.9	703	260	8.3	164	2940	93.3	131	5512	174.8
22	958	158	5.3	720	266	8.8	168	3009	100.	134	5642	187.6
23	979	162	5.6	736	272	9.5	171	3077	106.9	137	5770	200.6
24	1000	165	6.	752	278	10.	174	3143	114.	140	5892	213.6
25	1021	168	6.4	768	284	10.8	179	3208	121.2	143	6016	227.2
26	1041	172	6.8	783	290	11.4	183	3271	128.5	146	6134	241.
27	1059	175	7.1	797	295	12.	186	3333	136.	149	6252	255.
28	1080	178	7.5	812	301	12.7	189	3395	143.6	152	6364	269.
29	1100	181	7.9	826	306	13.4	192	3455	151.4	154	6478	283.8
30	1118	184	8.3	840	311	14.1	195	3514	159.3	157	6590	298.8
31	1138	187	8.8	854	316	14.8	198	3572	167.3	159	6698	313.8
32	1158	190	9.2	868	321	15.6	202	3629	175.5	162	6804	329.
33	1174	193	9.6	881	326	16.3	205	3685	183.7	164	6910	344.6
34	1192	196	10.1	894	331	17.0	208	3741	192.2	167	7014	360.4
35	1208	199	10.6	907	336	17.8	211	3795	200.7	169	7118	376.4
36	1226	202	11.	920	341	18.5	214	3849	209.4	172	7220	392.6
37	1243	205	11.5	933	345	19.7	217	3902	218.2	174	7318	409.2
38	1258	207	11.9	946	350	20.1	221	3955	227.	176	7416	425.8
39	1276	210	12.4	959	355	20.9	223	4006	236.1	178	7512	443.
40	1292	212	12.8	972	359	21.7	226	4057	245.3	180	7608	459.8
41	1305	214	13.3	984	365	22.5	228	4108	254.5	182	7702	476.5
42	1321	217	13.8	996	369	23.4	231	4158	263.8	184	7796	494.
43	1336	220	14.3	1008	374	24.2	234	4207	273.4	186	7888	511.8
44	1352	222	14.8	1019	378	25.1	237	4256	282.9	188	7980	529.8
45	1367	225	15.3	1031	382	25.9	239	4304	292.6	191	8070	548.
46	1382	227	15.8	1042	387	26.8	242	4351	302.4	193	8159	566.3
47	1397	229	16.3	1054	391	27.7	245	4398	312.3	195	8247	584.9
48	1412	232	16.8	1065	395	28.6	247	4445	322.1	197	8334	603.6
49	1426	234	17.3	1076	399	29.5	250	4491	332.5	199	8421	622.6
50	1441	237	17.9	1087	403	30.4	252	4536	342.7	201	8506	641.7

How Turbine Tests are Made

VERY early in our history we fitted up a testing flume at our works, equipping it fully with all the facilities and appliances required for weighing the power of a turbine and measuring the water discharged, in the most approved and accurate manner. Here were tested all our early made wheels, and from the data obtained were computed the tables of horse-power published in our catalogues.

These tables were correct beyond question, as proven frequently in practical operation and later by tests of impartial parties. Many contended, however, that these tests were of no value and even made the assertion that an accurate test was a scientific impossibility.

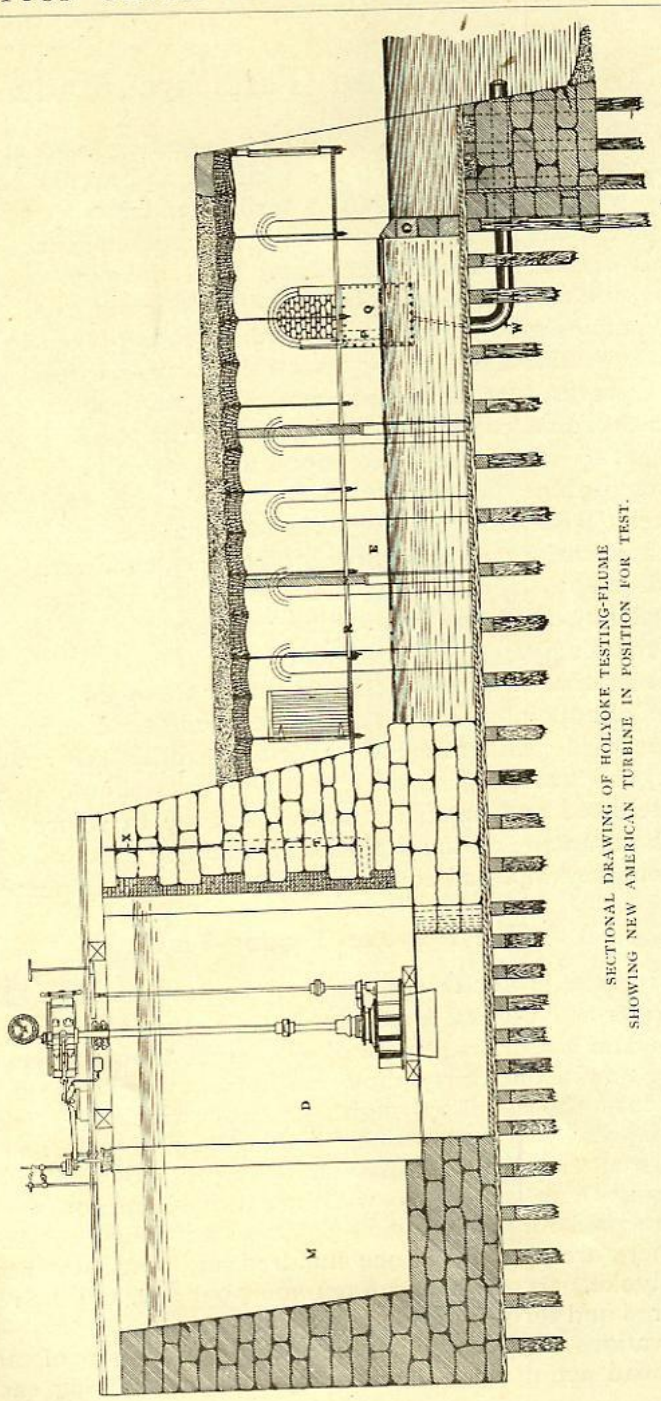
Strange to say, these contentions were prompted and fostered mainly by turbine builders themselves, and with evident purpose. Many freak wheels were being foisted upon the market, which by fanciful applications of water, double buckets, etc., were claimed by their builders to develop anywhere from 100 per cent to double the actual power of the water, and the power of the wheels was tabled accordingly.

As all legitimate tests failed to confirm these extravagant assertions, the disappointed theorists took refuge in condemning the test. It became evident, therefore, in order to establish the results of our wheel beyond question or doubt, that the tests should be conducted by disinterested and impartial parties, and we therefore, among the first, took advantage of the facilities afforded by the Holyoke Water-Power Company who had equipped a flume for testing purposes.

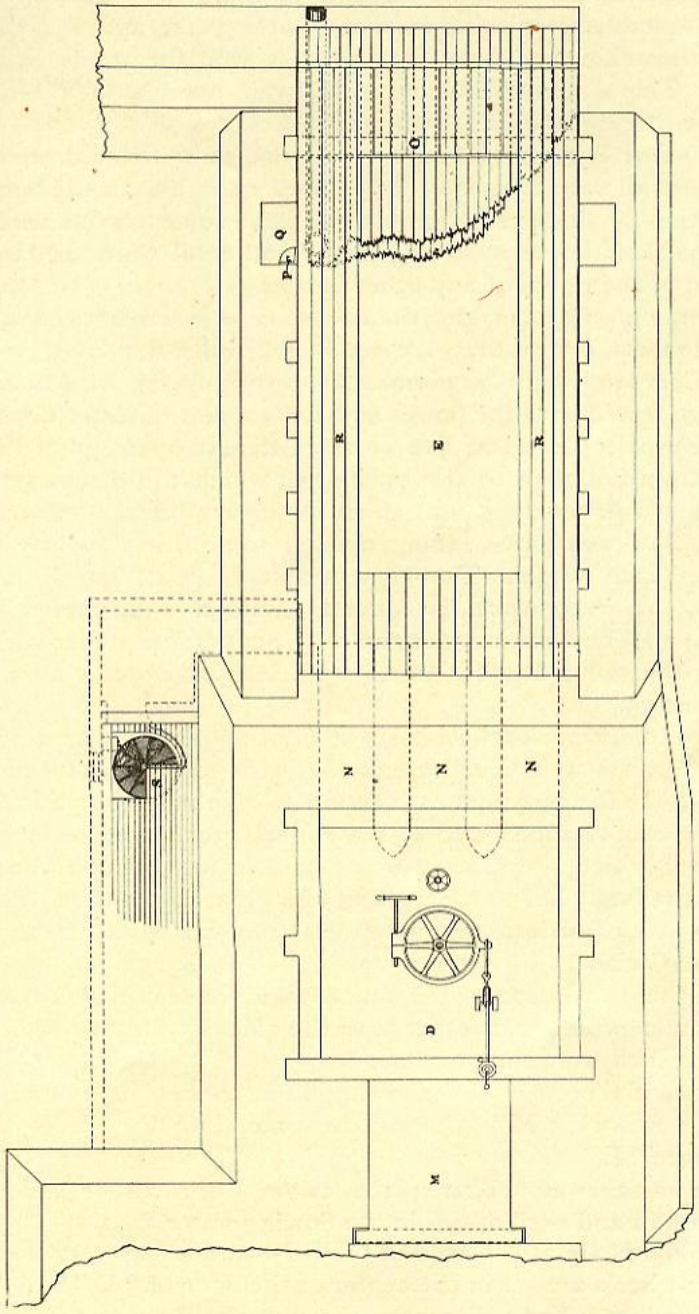
The Holyoke Testing-Flume

The Holyoke Water Power Company controls the flow of the Connecticut river at Holyoke, Massachusetts, on a fall of nearly sixty feet. Above its dam is a drainage area of over eight thousand square miles. There are now about thirty thousand horsepower in use by day and about twenty thousand by night, part of which are "permanent powers," held by the parties using them under indentures and subject to annual rental, and the balance are "surplus powers," held by the parties using them, subject to withdrawal at short notice. Surplus powers are paid for from day to day, and according to the amount used. There are now about one hundred and sixty water wheels in use in Holyoke, part of which run ten hours per day, and the remainder one hundred and forty-four hours per week.

Observations are taken giving the opening of the gate of each wheel and the head acting on it, once a day, and once during each night.



SECTIONAL DRAWING OF HOLYOKE TESTING-FLUME
SHOWING NEW AMERICAN TURBINE IN POSITION FOR TEST.



PLAN OF HOLYOKE TESTING-FLUME.

From these are computed the amounts discharged by each wheel and by each establishment during the quarter year, and the "surplus power" thus shown to have been used is paid for at the end of the quarter. This system results in economy in the use of water, where otherwise there would be great wastefulness.

In times of low water it restricts the use of water, and, when need be, confines all parties to their indentured quantities, while before the introduction of this system of management some parties used much more than their lawful quantity at any and at all times, and in entire disregard of the rights of any other parties.

For the purpose of making the necessary experiments on the wheels of their tenants, before they are set in the mills, the Holyoke Water Power Company built a permanent testing-flume, in which these wheels are tested both for power and for amount of water discharged. They are usually tested at five or six different openings of the gate, ranging from full open to the opening at which the discharge is one-half that at full opening, and at six or eight different velocities of revolution at each gate-opening, making some thirty to fifty experiments on each wheel. The final result is, that for all practical purposes, the water-wheel is converted into a water-meter, and its discharge may be known under any of the conditions under which it is found in the mill. Besides this, its efficiency, or value, as a motor, is also known.

Being fitted to make these tests at any time, summer or winter, and with many tests to make, the expense of a single test need be but moderate. In former years such tests could be made only in the mills where the wheel happened to be set, and at great expense for preparation, all of which preparation was available for that one wheel only. This has gradually led to the making of a great many wheel-tests each year for outside parties, sending wheels from all parts of the United States and Canada.

From the description of the flume it will be seen that it is suitable for hydraulic experiments other than the efficiency test of wheels, and is used for such from time to time.

The essential portion of the testing-flume consists in the main of the trunk or penstock, "M" bringing the water into the wheel-pit "D," and tail-race "E."

In the passageway "M" are placed two sets of racks, or baffleboards, to stop eddies and oscillations in the flowing water.

Baffleboards are also placed in the tail-race for same purpose.

Flume-wheels are set in the center of the floor of "D," and "D" is filled with water. They discharge through the floor of "D" and out

of the three culverts "N N N" into the tail-race "E." At the down-stream end of this tail-race is the measuring weir "O," the crest being formed of a piece of planed wrought-iron. It can be used with or without end contractions. The depth of water on the weir is measured by a hook-gauge, in a cylinder "P," set in a recess, "Q," fashioned into the sides of the tail-race. These recesses are water-tight, and the observer is thus enabled to stand with the water level about breast-high, or at a convenient height for accurate observation. The methods of measuring water over this weir are those described in Lowell Hydraulic Experiments, by James B. Francis.

A platform "R" surrounds the tail-race, and is suspended from the iron beams that roof it in. Above the tail-race is a street. The wheels to be tested arrive on this street, are lifted from the wagon or cars by a traveling windlass that runs on a frame-work over the street, are run into the building and lowered into the wheel-pit "D." Winding stairs "S" lead into a passageway that leads in turn to the platform "R." In the well-hole of these stairs is set up the glass tube "X," which measures the head of water upon the wheel. It is connected with the pit "D" by means of pipe running through a cast-iron pipe "T," built into the masonry dam which forms the down-stream end of the wheel-pit "D." The power is weighed by a Prony brake, consisting of a cast-iron pulley, surrounded by a wood-lined jacket, cooled and lubricated by water from the city mains, or, if necessary, with the addition of a small stream of soap-water. The pull of the jacket is weighed by a bent lever and weights, the friction being regulated by an attendant at the temper-screw, so that the weights are kept balanced. To enable the observer at the brake-wheel, the one at the head-gauge, and the one at the measuring-weir, to take simultaneous observations at intervals of one minute, an electric clock is set up, which rings three bells simultaneously at intervals of one minute, or of half a minute if desired.

The whole structure is built in a durable and efficient manner. The pits and tail-race are all lined with brick laid in cement. The stone masonry was intended, by careful work and grouting, to be water-tight without the brick lining, and the brick lining was then carefully laid up with joints full of mortar, as an extra precaution. As a consequence, the front of the wall forming the down-stream side of the pit "D" is barely damp with twenty feet head of water upon it. The floor of the pit "D" is built so tight that an exact measurement of the leakage of the wheel-gate could be made, if desired. An approximate estimate is readily made by filling the pit before the tail-race is allowed

to fill up, and apportioning the total measured leakage of the wheel-gate and that of the flume.

"W" shows a waste-pipe. Another not shown serves to draw the water out of and through the floor of the pit "D." To close or open these waste-pipes they are fitted with cases of small water-wheels, which thus form convenient valves for the purpose indicated.

The pipe "W" leads into a sewer on the other side of the second level canal, and thence into the river. It enables the tail-race to be emptied of water down to within some three inches of the bottom planking.

After the wheel to be tested is placed in the flume, and the dynamometer placed on the shaft, the lever is adjusted — care being taken that it is horizontal, and tangent to the circumference of the brake at point of application of the pull. It is balanced by placing a small weight first on one side and then on the other of the fulcrum, and at equal distances from it, and noting the time necessary to move the long arm a certain distance above and below the centre, and then adjustment of the counterpoise until the times become equal. A dash-pot is always used with the lever to steady its oscillations.

An indicator is attached to the turbine-gate or to the mechanism controlling it, so that the position of the gate is always known.

The hook-gauge is set by an engineer's level so that point of hook is level with crest of weir, when scale on the gauge reads zero. The length of weir is adjusted to the proper length for the quantity of water to be measured. The floating-gauge, by which head on wheel is measured, is adjusted so that the zero of its scale is at the level of tail-water.

In the system followed, there are three observers, each taking a reading of his guage every minute, and keeping a separate set of notes. The notes from which the theoretical or gross power of the water is computed, are kept by the men at the head-gauge and hook-gauge, and consist of a simple measurement of the head, or vertical distance from surface of water in flume over the wheel, to surface of tail-water; the length of the measuring weir, the number of its end contractions, depth of water flowing over weir, and temperature of water.

All data for the effective power of the wheel are taken by the third observer, and consist of the circumference of the brake at point of application of the weight, ratio of the lever arms, number of pounds on the lever, revolutions of the wheel per minute, and setting of the wheel-gate.

Of the data, all excepting setting of the gate, weight on lever, revolutions, head and depth on the weir, are generally constant throughout one wheel test.

The variable data are compared with each other and for any one experiment, consecutive readings are selected where everything goes to show that revolutions, head, and depth on the weir are steady and consistent with each other. These readings in each note-book are then averaged, and these averages compose the variable data for the experiments, a full set for each change of weight on the lever.

The quantity of water passing the weir is computed by the Francis formula:

$Q. = 3.33\ (L - .1\ n.\ h.)\ h.^{3/2}$ in which

Q. = quantity in cu. feet per second.

L. = length of weir in feet.

n. = number of end contractions.

h. = depth on the weir.

If the volume of water renders it necessary, Q. is corrected for velocity of approach.

Q. is then diminished by the leak of flume floor, and result is the net quantity of water passing the wheel.

Theoretical power of water in horse-power is

$$\text{H. P. (water)} = \frac{q \times H. \times 60 \times Wt}{33{,}000}$$

in which q = cubic feet per second passing the wheel.

H. = head on wheel, in feet.

Wt. = weight in pounds of one cubic foot of water, according to temperature.

Effective power of wheel is

$$\text{H. P. (wheel)} = \frac{W. \times R. \times l \times c}{33{,}000}$$

in which W. = weight in pounds on lever-arm.

R. = revolutions per minute.

l. = ratio of lever-arms.

c. = circumference of brake.

$$\text{Efficiency of wheel} = \frac{\text{H. P. (wheel)}}{\text{H. P. (water)}}.$$

On account of fluctuations in height of the canal from which water is drawn for testing, and on account of varying depth of water over the weir, the head on wheel is not constant throughout test, so that the discharges at various gates and speeds cannot be directly compared, but must first be reduced to a uniform head, H′, by the rule

$$q' = q \sqrt{\frac{H'}{H}}$$

The discharge at full gate and at the speed of revolution giving the maximum efficiency, is taken as the *unit discharge*, and the discharge (q′) of each experiment is divided by it, so that in the final report, the column of "proportional discharge" shows the percentage of water used in each experiment.

Deductions from Tests

Having given above a full description of how a test is made, we now explain how the horse-power, speed and amount of water discharged by the same wheel under any head is deduced from such a test. We do this, in the first place, to enable anyone who so desires to determine for himself whether a wheel that has been tested and the test made known has been correctly tabled as to its horse-power, speed and amount of water discharged, or in other words whether such table has been actually deduced from such test; in the second place, to show that a wheel that has not been tested cannot be correctly or reliably tabled as to its horse-power, speed and discharge, as the data required for these deductions can only be obtained by means of a test. To illustrate: The *theoretical discharge* of a wheel under a given head can be ascertained by measuring the cross-section or area of its discharging openings and multiplying same by the theoretical velocity of the water under the given head, but the *actual discharge* can only be ascertained by measurement, over a weir, of the amount of water *actually* discharged by the wheel when in operation, and this is *one* of the objects of a test. The ratio of the actual discharge to the theoretical discharge is called the coefficient of discharge.

The discharge being known, the *theoretical power* of the water can be ascertained by computation by formula given elsewhere, but the *actual power* of the wheel can only be ascertained by measurement with a dynamometer or other appliance; and this is another of the objects of a test. The ratio of actual power developed to the theoretical power is the efficiency of the wheel or the percentage of useful effect.

The speed of a wheel of given diameter under a given head is due to the velocity of water under that head, and the ratio of the actual speed to the theoretical speed is the coefficient of speed or relative velocity; and to ascertain the proper speed is also one of the objects of a test. Without these three coefficients it is impossible to table a wheel as to power, speed and discharge; and until the wheel has been tested and the actual power, speed and discharge ascertained, these coefficients cannot be determined.

It is absurd to contend that the judgment of anyone to determine these coefficients is superior to determining them by actual test, whether the accuracy or science of a test is conceded or not. Therefore any tables of power without an accompanying test to show how same have been deduced should be condemned at once as unworthy of time or attention, and any tables of power accompanied by test

should be carefully examined to ascertain whether same have been correctly deduced. Such a course will save the purchaser the expenditure of money and avoid future trouble.

The potential energy of a mass of water is its weight multiplied by the distance it has to fall. This product of the weight into the head gives the work the water performs in foot pounds. Thus 1,000 cubic feet of water weighs 62,333 pounds, and falling 10 feet develops 623,330 foot pounds of energy. If it is 1,000 cubic feet per minute, dividing by 33,000 gives the horse-power.

The horse-power a turbine will develop from this quantity of water depends upon the efficiency of the wheel as ascertained by test.

The quantity of water (say in cubic feet per second) which will discharge (theoretically) through an aperture under a given head is ascertained by multiplying the area of the aperture in square feet by the velocity of the water in feet per second due that head; and, the area of the aperture remaining the same, the quantity discharged under different heads varies as the velocity under different heads. So the quantity under any head being known, the quantity under any other head may be ascertained by the proportion $Q : Q' :: V : V'$, or $Q' = \frac{QV'}{V}$. In the same way the quantity of water discharging through a turbine under different heads varies as the velocity of water due those heads.

Having by test measured the quantity of water discharged by the turbine, and the head also having been carefully measured, the discharge under any other head is obtained by the above formula and entered in the table.

Having thus ascertained the discharge in cubic feet per minute for any head, the horse-power is obtained as already explained, by multiplying the quantity by $62\frac{1}{3}$, the weight of a cubic foot of water, this product by the head in feet and dividing the result by 33,000 and multiplying by the per cent of useful effect, or by the formula (2) $\text{H-P} = \frac{Q \times 62\frac{1}{3} \times H}{33{,}000} \times \%$ efficiency. The per cent of efficiency is obtained by dividing the actual horse-power by the theoretical horse-power.

It will be seen in formula (2) that the horse-power varies as the quantity and the head, the other elements of the formula remaining constant. We have already shown that the quantity varies as the velocity. (The quantity consisting of two factors, the velocity and the vent of the wheel—the latter being always constant.) Therefore the horse-power varies as the velocity and the head, and the horse-power under any head being known, the horse-power under any other

head can be ascertained by the proportion, H-P : H-P′ :: V X H : V′ X H′, or the formula (3) $H\text{-}P' = \frac{H\text{-}P \times V' \times H'}{V \times H}$.

The speed of a wheel is due to the velocity of the water which drives it. For example, the velocity of water due fourteen feet head is thirty feet per second, or 1,800 feet per minute. A wheel three feet in circumference, therefore, would make 600 turns per minute. This would be the theoretical speed of the wheel without regard to contracted discharge. The actual speed is taken during the test by an indicator, and the relative velocity ascertained. It follows, therefore, that the revolutions vary as the velocity, and the revolutions under any head being known, the revolutions under any other head may be ascertained by the proportion, R : R′ :: V : V′, or the formula (4) $R' = \frac{R \times V'}{V}$.

It will be noticed in examining the above formulæ that the quantity of water and the revolutions vary directly as the theoretical velocity due the head, and that the horse-power varies directly as the velocity and the head. From these formulæ, and with a test as the basis, the horse-power, speed and quantity of water discharged of any wheel can be easily computed for any head.

Without a test as a basis, it is necessary to compute the discharge from the vent of a wheel, which can be easily measured, and *assume* the coefficient of discharge, then compute the horse-power by *assuming* the percentage of useful effect and approximate the revolutions by *assuming* the relative velocity.

Tests of the New American

IT was in 1894 that the first wheel of our new line was perfected and tested. These wheels we designated at the time Special to distinguish them from the regular or standard line. The capacity of the wheels was increased about fifty per cent in power, and the efficiency was brought up as shown by the tests to a point never yet reached by any turbine. The first wheel was a forty-five-inch right-hand, and was tested July 9, 1894, and the following is a synopsis of the test, showing the results at different stages of gate from whole to half water:

Test of a 45-inch Wheel, July 9, 1894

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	16.06	119.17	141.58	205.27	79.76
⅞ Gate	16.42	122 00	127.18	195.19	82.58
¾ Gate	16.78	117.33	112.60	175.74	82.18
⅝ Gate	17.03	111.83	98.12	149.99	79.31
½ Gate	16.88	118.67	82.07	118.40	75.52

The results fully met our expectations and the forty-two-inch wheel, which had been worked out on the same lines, was tested July 14, 1894, with the following results:

Test of a 42-inch Wheel, July 14, 1894

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	16.33	128.00	134.18	199.56	80.50
⅞ Gate	16.56	134.80	120.85	188.14	83.09
¾ Gate	16.59	129.33	104.85	162.89	82.77
⅝ Gate	17.13	125.25	92.76	142.40	79.21
½ Gate	17.48	121.00	70.80	98.85	70.60

A comparison of the results of these two wheels is graphically presented in the diagram, Fig. 7, prepared by Mr. A. F. Sickman, of the Holyoke Water Power Company.

The vertical lines indicate the percentage of useful effect, the horizontal lines the discharge, and the intersection of these lines with the curved lines the efficiency at different degrees of gateage from whole to half water for each of the wheels.

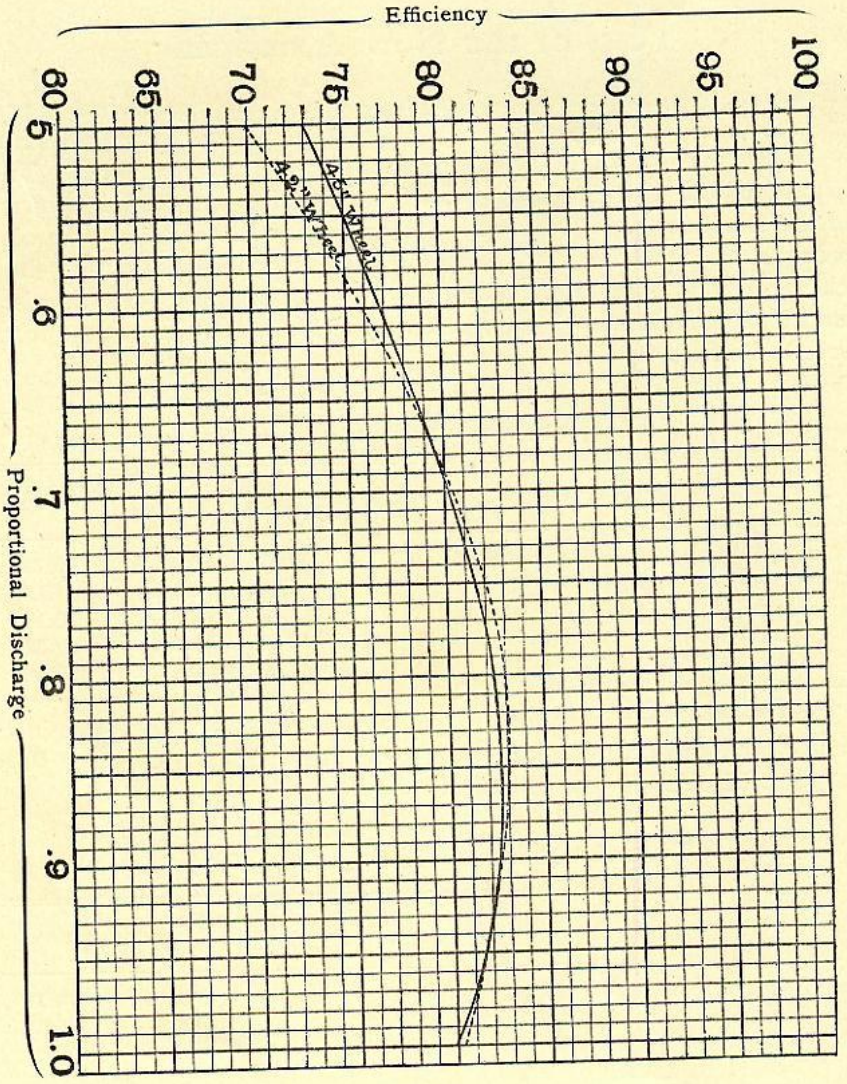


FIG. 7.

The diagram shows that the performance of each was very nearly uniform at each point, a remarkable achievement in turbine building. The result of these two tests demonstrated that we had the correct lines, and proved our ability to build two wheels of different sizes to give the same results. Acting on this established fact, the entire line of wheels was developed and various sizes tested from time to time, the results of which are given herewith.

Test of a 51-inch Wheel, March 12, 1896

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	15.03	100.00	192.94	262.11	79.70
⅞ Gate	15.46	96.75	175.98	254.91	82.61
¾ Gate	15.96	96.25	155.60	230.01	81.66
⅝ Gate	16.44	90.00	139.25	202.20	77.88
½ Gate	17.10	96.25	110.76	153.99	71.69

Test of a 57-inch Wheel, Left-hand, August 27, 1896

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	14.04	87.00	230.95	293.11	79.88
15/16 Gate	13.47	85.20	219.61	269.65	80.55
9/10 Gate	13.70	87.50	205.96	262.04	82.06
¾ Gate	14.21	77.67	182.24	232.60	79.37
⅝ Gate	15.62	76.75	158.88	203.73	72.54

Test of a 57-inch Wheel, Right-hand, September 1, 1896

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	14.32	88.12	230.95	299.12	79.88
15/16 Gate	14.45	86.60	220.60	294.55	81.61
9/10 Gate	14.91	86.75	212.50	295.06	82.25
⅞ Gate	15.12	83.87	203.62	285.26	81.84
¾ Gate	15.55	82.12	192.79	273.72	80.64
⅝ Gate	16.00	79.37	165.36	224.06	74.79

Test of a 60-inch Wheel, November 10, 1898

	Head	Rev. per minute	Cubic feet per second	Horse-power	Per cent
Whole Gate	10.65	77.87	244.12	232.68	78.92
15/16 Gate	11.27	77.00	241.88	248.38	80.35
9/10 Gate	12.96	84.50	244.60	295.53	82.21
⅞ Gate	13.20	81.50	232.60	285.04	81.86
8/10 Gate	14.32	80.12	226.59	299.25	81.33
¾ Gate	14.64	76.75	211.53	276.24	78.66
⅝ Gate	14.83	76.37	196.11	248.94	75.48

Report of Tests

TESTING FLUME OF THE HOLYOKE WATER POWER CO.,
HOLYOKE, MASS.

(*Copy*)

Report of tests of a right-hand New American turbine wheel designed and built by the Dayton Globe Iron Works Co., No. 1111, made May 27 and 28, 1898. Gate No. 1112. Rated a 36-inch wheel. Tested on special draft-tube.

Number of the experiment	Proportional part of the full opening of the Speed-gate; in per cent	Proportional part of the full discharge of the wheel; being the discharge at full gate when giving best efficiency, in per cent	Head acting on the wheel; in feet	Duration of the experiment; in min.	Revolutions of the wheel; per min.	Quantity of water discharged by the wheel; cubic ft. per sec.	Power developed by the wheel; H. P.	Efficiency of the wheel; in per cent
8	1.000	1.017	16.67	4	133.50	116.61	179.58	81.52
7	1.000	1.012	16.71	5	139.25	116.11	181.32	82.47
6	1.000	1.006	16.72	4	143.50	115 50	180 69	82.56
5	1.000	1.001	16.72	4	148 00	114.90	180.90	83.09 full
4	1.000	0.997	16.73	4	152.75	114.51	180.14	82.97
3	1.000	.992	16.75	4	157.50	113.92	178.97	82.76
2	1.000	.987	16.76	4	163.50	113.43	177.76	82.50
1	1.000	.980	16.74	4	170.00	112.58	172.29	80.67
24	0.77	.945	16 90	3	130.67	109.06	173.36	83.00
23	0.77	.937	16.99	4	137.62	108.45	175.82	84.20
22	0.77	.932	17.00	4	143.25	107.86	176.85	85.11
21	0.77	.927	16 99	3	149.50	107.26	177.22	85.81 15/16
20	0.77	.922	17.02	5	155.50	106.80	176.70	85.77
19	0.77	.915	16.98	4	161.75	105.85	173.86	85.36
18	0.77	.901	17.02	4	166.25	104.31	168.49	83.74
17	0.77	.881	17.02	4	172.00	102.09	158.47	80.48
16	0.67	.883	17.00	4	131.50	102 19	164.77	83.70
15	0.67	.878	16.98	4	136.00	101.60	165.40	84.60
14	0.67	.875	16.97	4	141.00	101.15	166.28	85.48
13	0.67	.871	16.97	4	145.75	100.69	166.51	85.99
12	0.67	.864	16.98	4	152.00	100.00	166.18	86.36 7/8
11	0.67	.855	16.98	3	156.00	98.95	162.89	85.56
10	0.67	.844	16.99	4	159 50	97.70	158.71	84.37
9	0.67	.826	17.03	4	165.50	95.74	152.48	82.52
31	0.59	.859	17.00	4	132.25	99.41	160.03	83.55
30	0.59	.855	17.01	5	138.80	98.95	161.98	84.92
29	0.59	.849	17.02	4	144.75	98.36	162.70	85.76
28	0.59	.842	17.03	4	150.50	97.59	161.77	85.89 11/16
27	0.59	.830	17.06	4	154.00	96.20	157.97	84.93
26	0.59	.822	17.00	4	156.83	95.19	153.16	83.52
25	0.59	.809	17.12	4	163.00	93.92	150.18	82.41
39	0.48	.798	16.89	4	127.50	92.10	144.10	81.74
38	0.48	.795	16.90	4	133.25	91.77	146.50	83.35
37	0.48	.789	16.94	4	139.00	91.21	147.70	84.35 3/4
36	0.48	.781	17.01	4	142.50	90.40	146.17	83.88
35	0.48	.774	17.04	4	146.00	89.64	144.38	83.40
34	0.48	.763	17.09	4	149.50	88.60	142.33	82.94
33	0.48	.753	17.13	4	154.75	87.50	139.73	82.26
32	0.48	.732	17.25	4	162.87	85.30	135.05	80.99
46	0.32	.665	17.55	4	126.25	78.18	120.20	77.30
45	0.32	.659	17.53	4	130.50	77.43	119.43	77.64
44	0.32	.653	17.52	4	134 75	76.79	118.36	77.63
43	0.32	.647	17.38	4	138.12	75.73	116.23	77.92
42	0.32	.636	17 44	4	142.75	74.55	114.86	77.95 5/8
41	0.32	.631	17.24	4	143.87	73.50	111.34	77.54
40	0.32	.621	17.21	4	147.62	72.34	108 81	77.12
47	0.32	.606	17.80	4	160.75	71.73	108.61	75.06

During the above experiments, the weight of the dynamometer, and of that portion of the shaft which was above the lowest coupling was suspended by ball bearing. With the flume empty, a strain of 38 pounds, applied at a distance of 3.2 feet from the center of the shaft, sufficed to start the wheel.

HOLYOKE WATER POWER CO.

By E. S. WATERS, Hydraulic Engineer.

A. F. SICKMAN, Engineer in charge of experiments.

Report of Tests

(*Copy.*) TESTING FLUME OF THE HOLYOKE WATER POWER CO., HOLYOKE, MASS.

Report of tests of a right-hand New American turbine wheel designed and built by the Dayton Globe Iron Works Co., Dayton, Ohio, No. 1141, made September 15-20, 1898. Case No. 1112. Tested for Morgan Construction Co., Worcester, Mass. Rated a 36-inch wheel. Tested on special draft-tube.

Number of the experiment	Proportional part of the full-opening of the speed-gate; in per cent	Proportional part of the full discharge of the wheel; being the discharge at full-gate when giving best efficiency, in per cent	Head acting on the wheel; in feet	Duration of the experiment; in min.	Revolutions of the wheel; per min.	Quantity of water discharged by the wheel; cubic ft. per sec.	Power developed by the wheel; H. P.	Efficiency of the wheel; in per cent
9	1.000	1.023	16.91	4	131.25	116 13	179 20	80.60
8	1.000	1.016	16.93	3	137.00	115.41	180.33	81.52
7	1.000	1.011	16.97	4	142.37	114.91	181.28	82.11
6	1.000	1.005	16.97	4	147.25	114.30	181 17	82.50
5	1.000	1.001	16.99	4	151.62	113.93	180.97	82.57 full
4	1.000	0.997	17.02	5	156.00	113.56	180.45	82.46
3	1.000	.991	17.02	4	160.50	112.81	178.76	82.23
2	1.000	.985	16.98	4	165.00	112.08	176.69	82.00
1	1.000	.975	17.01	5	175.80	111.00	172.07	80.49
17	0.764	.943	16.74	4	132 75	106.45	167.81	83.19
16	0.764	.936	16.65	4	136.50	105.38	167.53	84.35
15	0.764	.932	16.64	4	142.25	104.90	168.47	85.27
14	0.764	.928	16 66	4	148 25	104.56	169.21	85.81
13	0.764	.922	16.64	4	154.50	103.85	168.76	86.27 15/16
12	0.764	.917	16.69	4	161.25	103.38	168.22	86.13
11	0.764	.907	16.70	4	167.75	102.30	164.70	85.17
10	0.764	.892	16.71	4	171.25	100.68	157 63	82.77
25	0.661	.895	16.69	4	133.75	100.90	160 87	84.39
24	0.661	.888	16.71	4	139.60	100.22	161.91	85.41
23	0.661	.883	16.71	5	145.50	99.65	162.50	86.21
22	0 661	.879	16.74	4	152.75	99.29	163.10	86.69 7/8
21	0.661	.871	16.81	4	159.50	98.60	162.48	86.60
20	0.661	.859	16.82	4	162.75	97 21	157.80	85.26
19	0.661	.848	16.83	4	166.12	95.97	152.91	83.64
18	0.661	.835	16.85	4	170.75	94.62	146.69	81.28
46		.850	16.92	4	131.50	96.54	156.14	84.43
45		.846	16.96	4	137.75	96 21	157.65	85.33
44		.841	16.98	4	143.37	95.61	157.92	85.92
43		.836	16.96	4	149.25	95.06	157.99	86.55
42		.828	16.99	4	154.75	94.25	156.21	86.16
34	0.572	.849	16.68	4	131.00	95.73	151.93	84.06
33	0.572	.844	16.69	4	138.12	95.19	153.41	85.31
32	0.572	.839	16.73	4	144.25	94.71	154.91	86.37
31	0.572	.831	16.75	4	150.75	93.92	154.49	86.76 11/16
30	0.572	.821	16.76	5	154.80	92.79	151.04	85.80
29	0.572	.810	16.80	4	158.87	91.65	147.21	84.46
28	0.572	.799	16.86	4	163.75	90.54	143.69	83.16
27	0.572	.787	16.83	4	168.00	89.07	139.18	82.02
26	0.572	.768	16 92	4	172.75	87.18	132.51	79.36
41	0.476	.789	17.23	4	131.25	90.41	146.59	83.13
40	0.476	.785	17.25	4	138.12	89.99	149.17	84.90
39	0.476	.777	17.28	4	144.00	89.19	148.45	85.10 3/4
38	0.476	.766	17.29	4	148.25	87.95	145.56	84.56
37	0.476	.753	17.29	4	154.25	86.40	141.98	83.97
36	0.476	.739	17.35	4	161.00	84.98	138.32	82.88
35	0.476	.721	17.33	4	165.50	82.80	132.03	81.28
54	0.306	.635	17.47	4	120.75	73.20	110.78	76.51
53	0.306	.631	17.40	4	127.25	72.66	112 06	78.28
52	0.306	.625	17.39	4	131.25	71.94	110.74	78.18
51	0.306	.618	17.34	4	135.50	71.00	109.34	78.44
50	0.306	.608	17.30	4	139.37	69.78	107.33	78.53 5/8
49	0.306	.596	17.37	4	146.50	68.56	105.63	78.34
48	0.306	.587	17.35	4	152.50	67.52	102.47	77.26
47	0.306	.578	17.35	4	160.25	66.41	97.85	75.00
60	0.208	.508	17.68	4	122.25	59.00	83.65	70.82
59	0.208	.502	17.69	4	129.12	58.24	83 59	71.66
58	0.208	.496	17.72	4	136.37	57.57	83.27	72.09 1/2
57	0.208	.491	17.73	4	142.50	57.01	81.76	71.44
56	0.208	.485	17.74	4	148.75	56.36	79.87	70.56
55	0.208	.478	17.78	4	156.25	55.59	76 23	68.12

During the above experiments, the weight of the dynamometer, and of that portion of the shaft which was above the lowest coupling was suspended by ball-bearing. With the flume empty, a strain of 8 pounds, applied at a distance of 3.2 feet from the center of the shaft, sufficed to start the wheel.

HOLYOKE WATER POWER CO.

A. F. SICKMAN, Engineer in charge of experiments. By E. S. WATERS, Hydraulic Engineer.

The pair of 57-inch wheels reported in the preceding tests were made for the Boston and Montana Consolidated Copper and Silver Mining Company, under a guarantee to develop eighty per cent average efficiency from three-quarters to whole gate, and 2800 horse-power, under forty feet head. (See cuts and description of plant, pages 61-63.) At the time the contract was entered into, the patterns for these wheels had not been made, nor had a wheel of this size ever been tested at Holyoke.

To a builder of the "cut-and-try" school, such an undertaking would have taken months of experimental work, much expenditure of money, and probable chance of failure. Following out the lines which we had established as correct, the necessary computation, drawings and patterns were made, the wheels built and both sent to Holyoke at the same time. The result did not come by chance, but by precise calculation and correct principles.

The 60-inch wheel, tested November 10, 1898, was one of a lot made for the Moline Water Power Company, Moline, Ill, and similarly guaranteed. This wheel, while not a new pattern, had never been tested. Its guaranteed performance, however, had not been a matter of guess-work, as the test demonstrated to the satisfaction of the Water Power Company.

The two tests of 36-inch wheels which are given in full, serve to illustrate a characteristic of New American wheels, which has already been commented on in describing their construction, viz: that all wheels of the same pattern are exact duplicates of each other, not only in construction but in performance.

The first report is that of a test made by us to ascertain the efficiency and power of the 36-inch wheel, in advance of filling a contract for eighteen wheels of that size for The Stora Kopparberg Bergslags Aktiebolag of Falun, Sweden.

The second was made under the inspection of the Morgan Construction Company, of Worcester, Mass., acting for the above Company, on a wheel selected at random from the entire lot by them. The result speaks for itself, as the second test slightly exceeded the first, demonstrating the superior manner in which all our wheels are fitted up.

But the crowning feature of these tests is the notable fact that the performance of this wheel surpasses in power and efficiency any 36-inch wheel ever tested at Holyoke, and relatively, of any other sized wheel.

While we have apparently reached the acme of perfection, yet are we not satisfied, and our experiments and tests shall go on as in the

past, until we feel that the *ne plus ultra* of the art has been scientifically attained.

In attaining these results there has been a great deal of personal satisfaction to ourselves. Turbine building is an art requiring the highest skill and an exhaustive knowledge of hydraulics and hydrodynamics; the development of a wheel entails research, thought, mechanical ingenuity and years of costly experiment. Users of wheels are quick to demand high results, but until convinced, slow to pay the price for a wheel of merit, attained by the expenditure of brains and money. Too often a cheap wheel backed up and guaranteed by cheap talk is given the preference on account of price, or placed on a par and used as a lever for discounting the wheel of merit. Such wheels, cheap in their construction, cost little in their manufacture, cheap in the amount of brains used in their design, cost nothing in their development, and cheap in the talk that sells them, cost nothing in the way of tests and experiments toward securing high power and efficiency.

In aiming at high results, it is scarcely necessary to say that we have looked equally after its manufacture as to mechanical construction and workmanship. The New American has cost money in its development, and no slight is permitted in its building. Skilled labor, up-to-date tools, and modern methods, make it what we desire it to be,—a high-grade machine.

It is in no sense a cheap wheel, yet to the discriminating buyer it presents greater value for the money than its cheap competitor. We make no claims for our wheel that we are not ready to substantiate by indisputable proof, or if necessary prove anew. We have advanced by steps in our continued experiments and tests, from one established truth to another, until we have reduced the art of turbine-building to a science. We believe we have accomplished what no others have attained,—the ability to build a wheel, to develop a given speed, power and efficiency, with a positive fore-knowledge of the results. This we have proven again and again. See report of test of 45-inch wheel, July 9, 1894, followed by 42-inch on same lines, July 14, 1894, 51-inch, March 12, 1896, 57-inch, August 27, 1896, 36-inch, May 27, 1898, and 60-inch, November 10, 1898. We have proven our ability to build two wheels of same diameter, right and left-hand, to give the same results. (See 57-inch.) We have proven our ability to build any number of wheels from the same patterns and give the same results. (See 36-inch.) We have the right principles; we have the right lines; and we know how to work to these lines to secure uniform results. Our method of casting our runners and cases by means of dry sand-cores, secures absolute uniformity, and the lines of each casting

conform absolutely with each other and with the original. Our method of fitting up the cases and gate-chutes, assures correct application of the water to the wheel and accurate conformity to the design. These results cannot be assured in other types of wheels, where the buckets of the runner are made separately of steel or cast iron, and the rim and hubs are cast around them, or where the buckets are riveted or bolted to the rim and hub, as any slight derangement of the buckets in shape or position will materially affect the power and efficiency of the wheel, and a previous test of a wheel of that construction is no assurance that a subsequent test will give the same results.

Even quite recently, the test of a wheel was not accepted by hydraulic engineers, much less by a doubting public, as a criterion for the power and efficiency of subsequent wheels from the same pattern, and a re-test of each individual wheel was necessary to establish its merit. Strange as this may appear, its solution is readily found in incorrect methods of construction and a lack of knowledge of the correct principle of turbine-building,—a natural concomitant of the "cut-and-try" system.

All of these barriers we have overcome, and to-day we occupy the unique position of standing alone in guaranteeing that each individual wheel we build will give the same results as shown in our published tests, or as nearly so as different conditions permit a test to repeat itself. We agree to submit to a test at Holyoke any wheel we put on the market, in accordance with this guarantee, the purchaser to pay all expenses attending such test if wheel equals the guarantee, or in event of failure we to bear all costs. This is a fair proposition. Will other builders do as much?

Vertical Wheels

THE simplest plan of a wheel-setting is a vertical outfit in a wooden, stone or iron flume. Where wood is plentiful and labor cheap, the wooden flume is certainly the cheapest plan that can be adopted, although not the best.

Any competent mill-wright can build a flume, or where desired we furnish plans to work by. The New American as already described is set up complete in our works and is ready for operation when shipped. It depends then for its successful operation on the skill of the mill-wright or erector in properly setting the wheel and driving gears and lining up the shafting. Full instructions for setting the New American are given on page 90, which should be carefully observed.

Iron flumes have proven, on account of their durability and their freedom from leakage, much superior to wooden penstocks. Although they are generally more expensive than wooden flumes, it is frequently the case that locations are such that iron flumes can be used to much greater advantage and at no greater expense. We especially recommend their use where wheels are to operate under high heads, as they are much stronger and more capable of standing the enormous strain to which they are subjected. The wheels are fitted to their places and accurately adjusted before shipment, and are therefore not liable to become deranged or out of line.

Figure No. 8, on the following page, represents one of our iron flumes, with wheel in position; and the table adjoining gives the dimensions of flumes for our different sized wheels. The top and bottom heads are made of cast iron, and the sides of boiler-iron, securely riveted together and calked to prevent leakage.

All of our iron penstocks are supplied with manholes, through which access can be had to the wheel, and with mouthpieces at the side, to connect with iron or wood supply-pipe. The top is also furnished with a combined follower and stuffing-box for the wheel-shaft; stuffing-box for the gate-shaft; and with a removable center-plate, so that the wheel can be taken out entire.

A boiler-iron draft-tube of any desired length may be attached to the bottom of flume, but is not included in the prices given in table.

Flumes over ten feet in diameter are made in halves, and can be put together at the place of erection.

These tables are for flumes to be placed under heads of fifteen feet or less, but prices and dimensions of those designed to work under greater falls will be furnished on application.

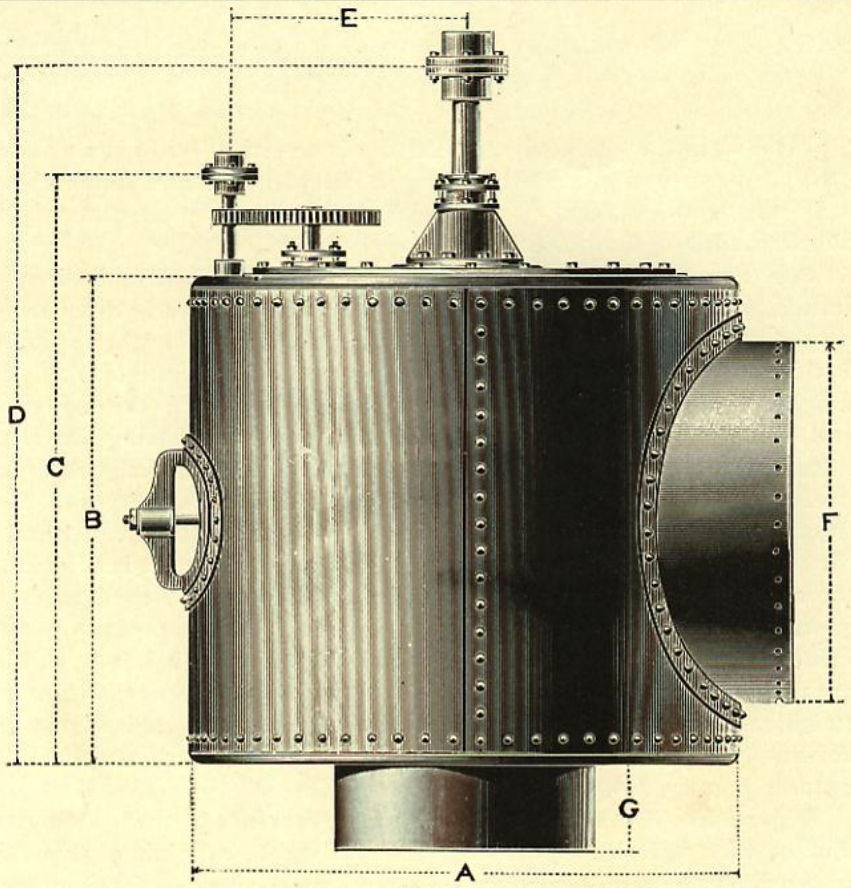


FIG. 8

Dimensions and Prices of Iron Flumes

Size of wheel	A	B	C	D	E	F	G	Price
13″	33″	39″	50″	62″	11″	23″	6⅞	$ 225 00
16″	42″	46″	62″	70″	14 3/16″	30″	8½	300 00
19″	51″	52″	69½″	78″	16¼″	36″	8⅞	375 00
22″	58″	57″	72″	83½″	19 7/16″	41″	13¼	450 00
25″	60″	59″	73″	86½″	18⅞″	43″	14	475 00
27½″	74″	68″	81½″	96¾″	22⅛″	52″	16	600 00
30″	78″	72″	85½″	97″	22½″	56″	16 3/16	700 00
33″	88″	79″	92½″	103″	26½″	63″	17	850 00
36″	95″	83″	98″	110″	28½″	67″	20	975 00
39″	104″	89″	104″	116″	30⅜″	73″	21½	1.075 00
42″	114″	96″	111″	123″	32⅛″	80″	19¾	1,225 00
45″	119″	99″	111″	123″	32 1/16″	84″	19⅞	1.400 00
48″	121″	101″	116½″	132″	35¼″	85″	21	1,550 00
51″	133″	110″	122″	144″	36⅞″	94″	23	1 850 00
54″	143″	117″	132½″	154″	38⅝″	101″	25⅝	2,050 00
57″	150″	121″	136½″	160″	42⅛″	105″	27⅝	2 250 00
60″	157″	127″	142½″	166″	43″	111″	28¾	2,500 00

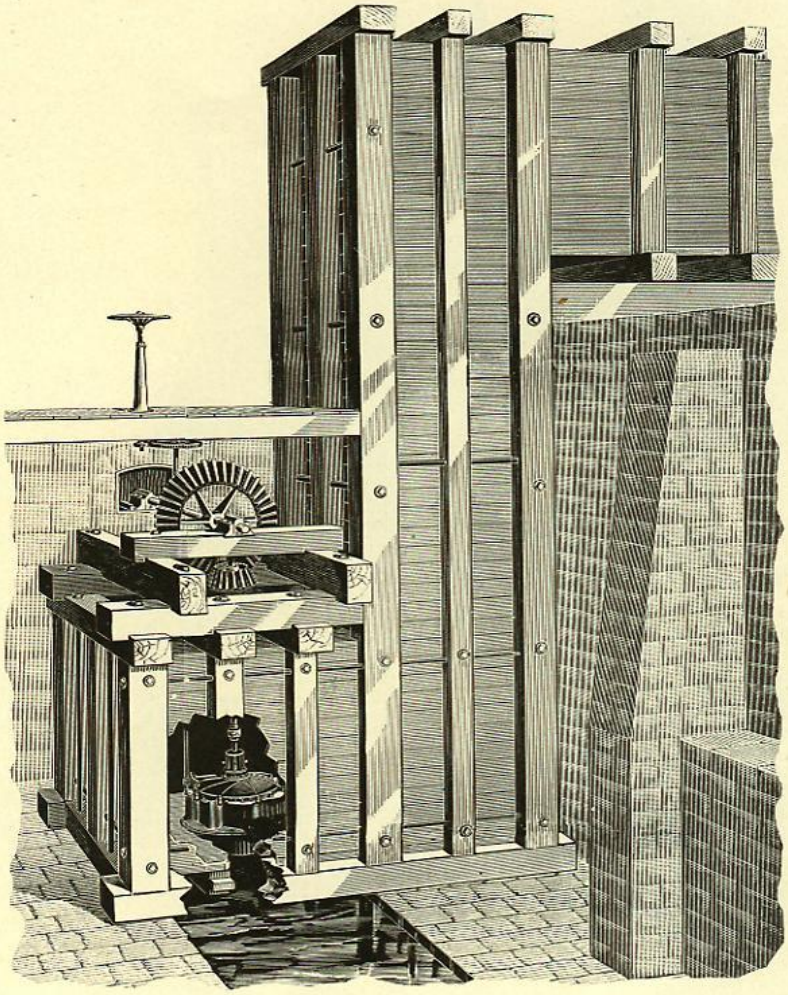


FIG. 9.

FIG. 9 shows the manner of setting our turbines in wooden penstocks, when the power is to be delivered below the line of head-water. It will be seen there are iron stuffing-boxes at the upper deck, through which the water-wheel shaft and gate-rod pass. These are packed to prevent leakage. The low portion of the penstock, occupied by the wheel, can be extended any desired distance, or the high and low portions may be separate and independent flumes, and the water conducted by a round cylinder, made of either iron or wood, of sufficient capacity to pass the water at a velocity not exceeding two feet per second.

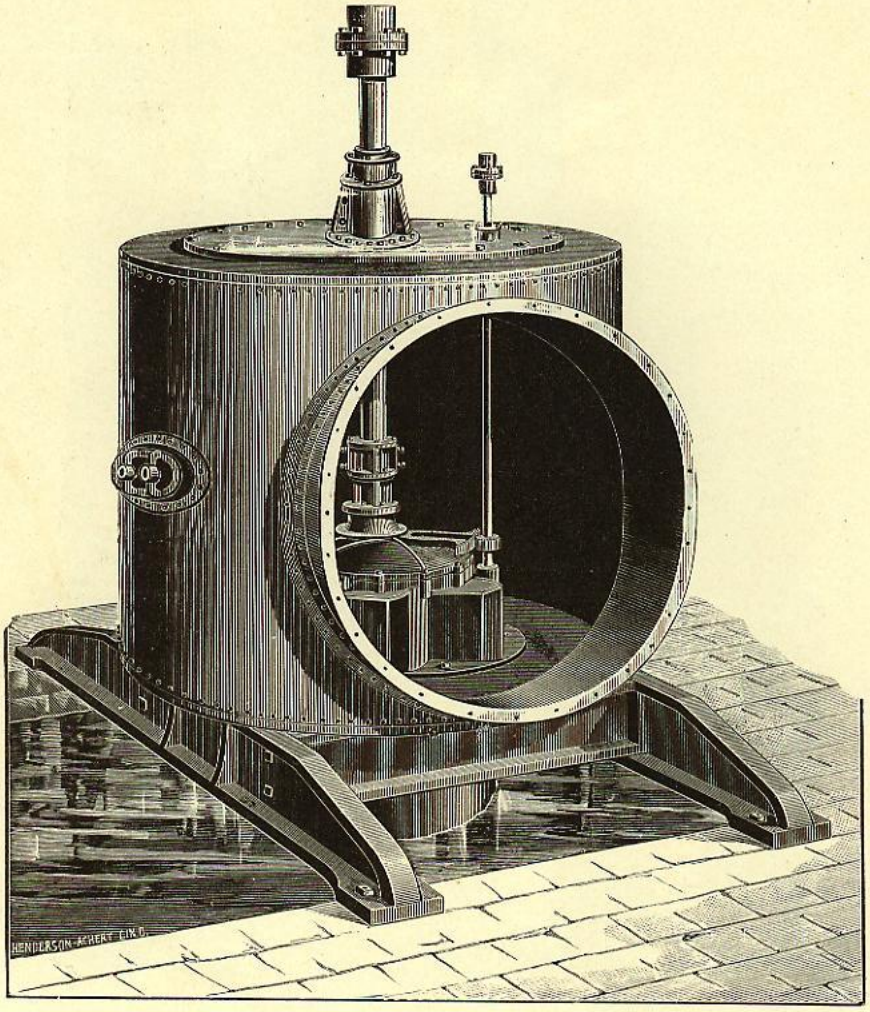


FIG. 10.

THIS illustration represents a vertical iron flume containing one of our New American Turbines resting on cast-iron girders. The girders are faced on their upper surface to receive the cast-iron plate of the flume, which is also faced on both sides; consequently, when the girders are level, the flume and wheel-shaft will be plumb.

The sleeve bearing on top of the flume is supplied with a stuffing-box, adjusted so as to make the shaft run true and prevent leakage. A manhole is provided in the side of the flume for access to the wheel.

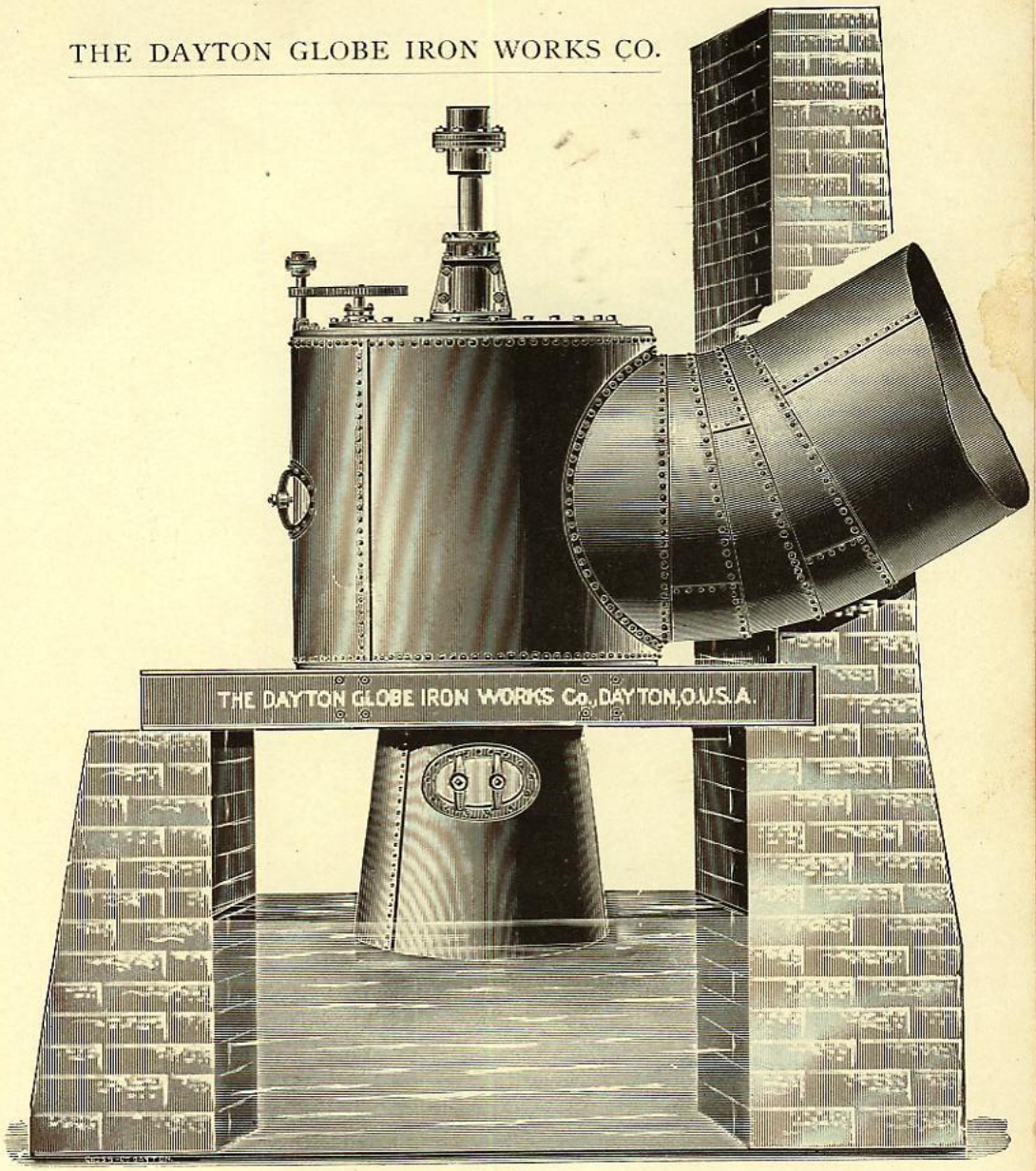


FIG. 11.

THE above cut shows an iron flume placed on steel girders with a draft-tube extending into tail-water, with a manhole in the draft-tube, through which access can be had to the step on which the shaft runs. The spider in which the step is placed is so arranged that the step and iron thimble can be taken out through the spider from below, and replaced without removing any parts but the step, thimble and plate on which the thimble rests. During this operation the water-wheel is held in place by a screw-jack. This manner of providing for replacing steps is advisable in the case of large turbines under high heads.

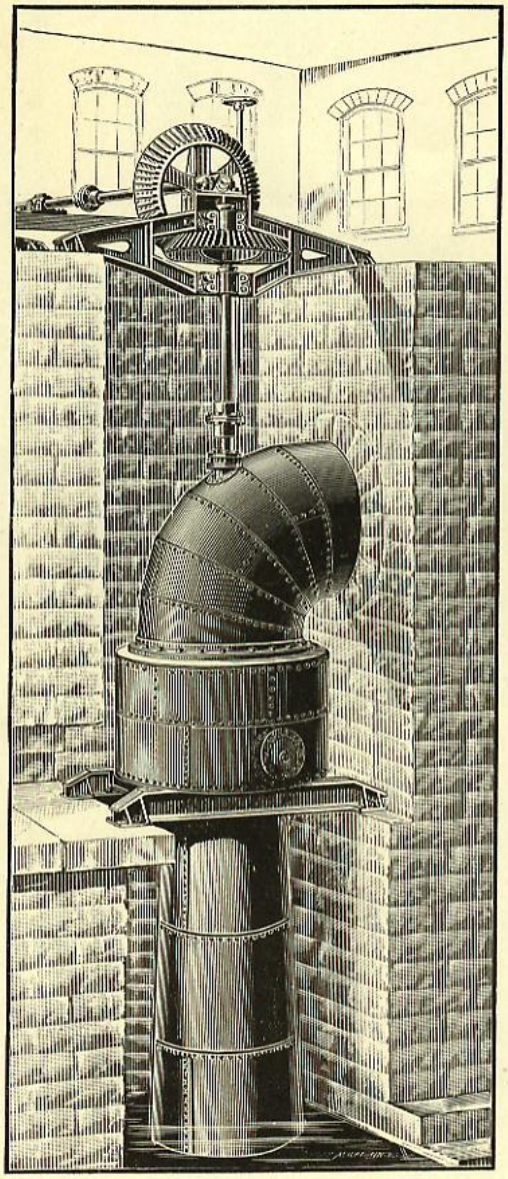


FIG. 12.

THE above cut represents an outfit consisting of a 66-inch New American Turbine in iron flume, located about twenty feet above tail-water, operating one of the largest flourmills in Minneapolis, Minnesota.

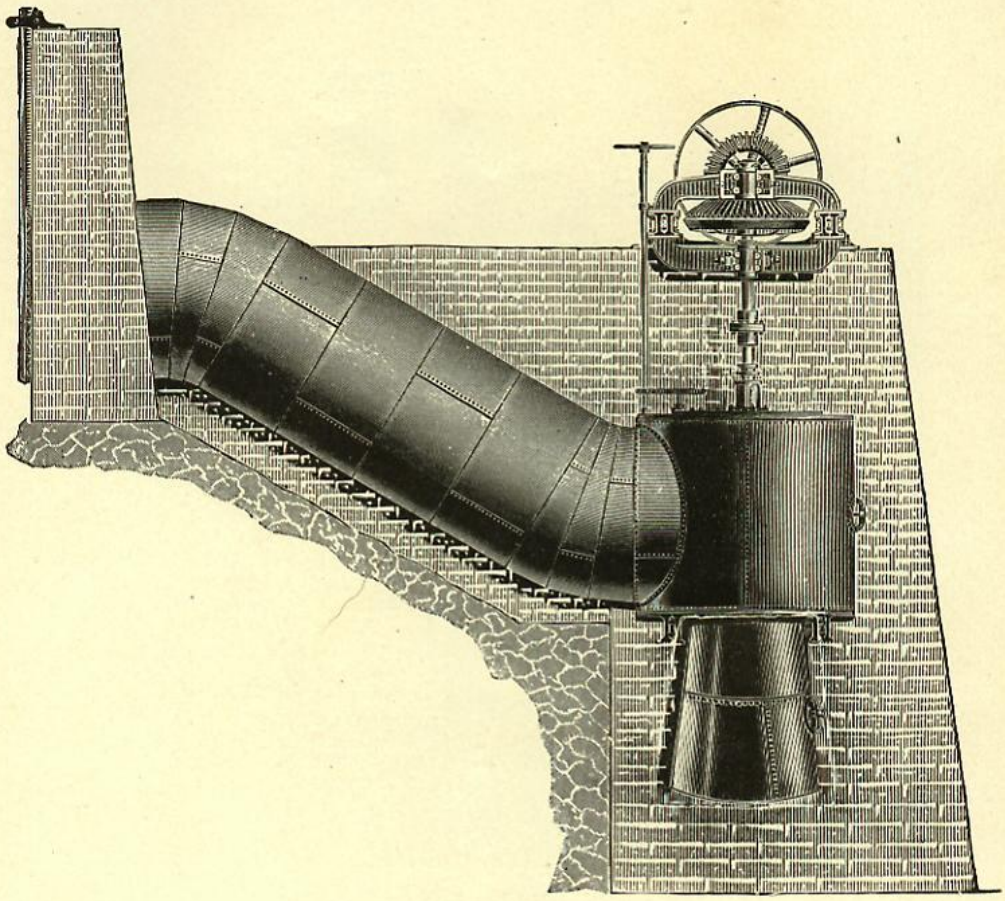


FIG. 13. SIDE VIEW.

FIG. 13 and Fig. 14 represent a 54-inch Special New American Turbine operating under 27-foot head and developing 522 horse-power. The entire outfit, consisting of iron flume resting on steel I beams, feed-pipe, draft-tube, driving-gears, and cast iron bridgetrees, was planned and furnished by us to the St. Louis River Slate Brick Co., of Duluth, Minnesota, and is of the most substantial and permanent character.

On the following page we print a letter from this firm, expressing their satisfaction with the plant.

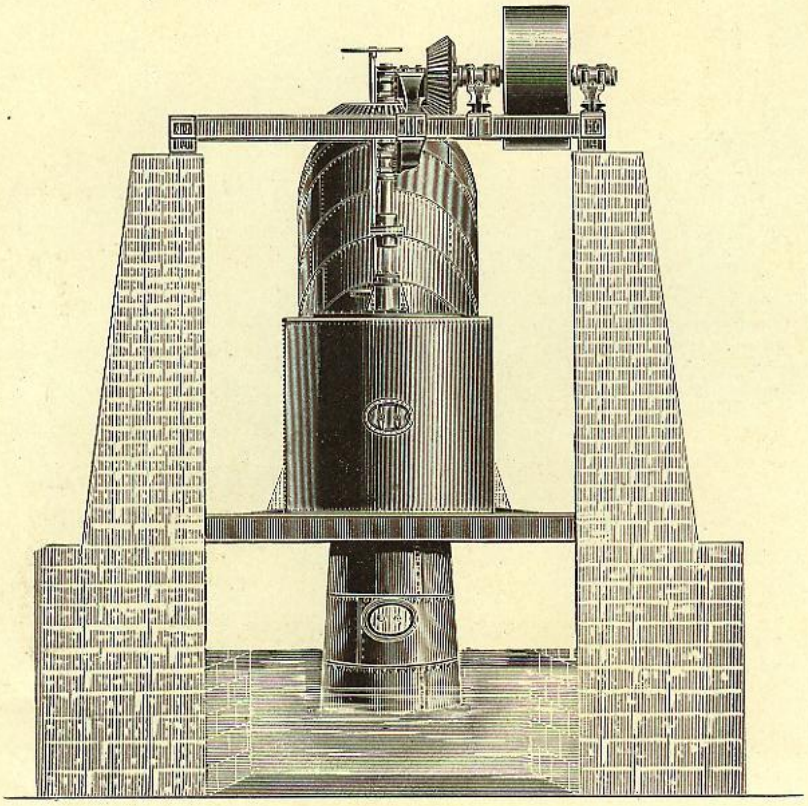


FIG. 14. END VIEW.

ST. LOUIS RIVER SLATE BRICK CO., DULUTH, MINN.

The Dayton Globe Iron Works Co., Dayton, Ohio:

I am pleased to state that the work done by your firm in behalf of the St. Louis River Slate Brick Co. is in every respect entirely satisfactory.

The 54-inch Special Wheel set in iron flume, supported by steel I beams, with all the supply pipes, draft-tubing, gearing, etc., works like a clock, and drives with tremendous force the immense amount of machinery of the entire plant. The wheel is running under a 27-foot head, and only about fifty to sixty per cent of its full power is being used to develop this power.

I feel that we can unhesitatingly recommend your work as being first-class in every particular. Very respectfully yours,

J. M. BUTLER.

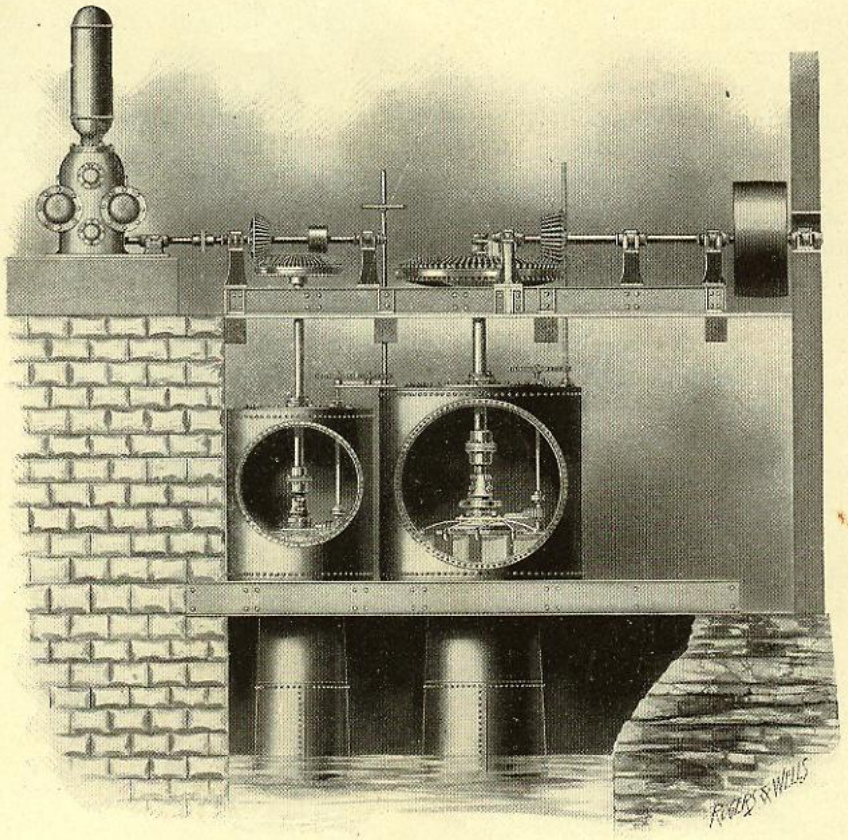


FIG. 15.

THE above engraving represents a pair of vertical wheels in iron penstocks, furnished The Little Falls Electric and Water Co., Little Falls, Minn., including feed-pipe, foundation-beams, iron harness and driving-gears. The wheels are a 30-inch and 48-inch and operate under 19 feet head, the former driving the pumps and the latter the electrical machinery.

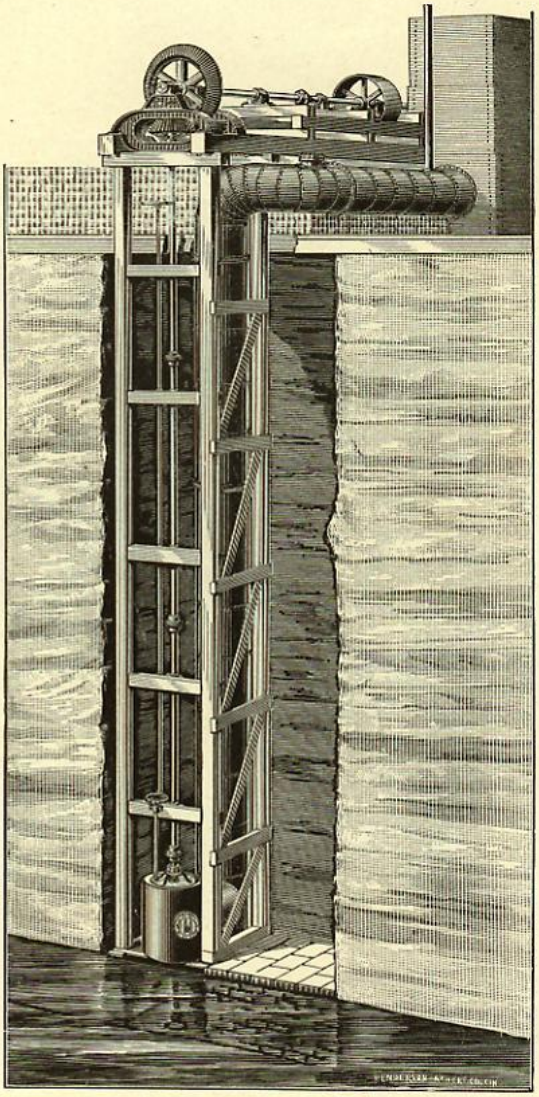


FIG. 16.

FIG. 17, on the following page, represents a pumping plant designed and furnished by our company to the city of Spokane, Washington, consisting of five 54-inch New American Turbines, four of which furnish power for four duplex Holly pumps, each of 3,000,000 gals. capacity per twenty-four hours. This plant is located on the Spokane River, about three miles from the business center of the city. The water is forced through about three miles of pipe to a reservoir elevated about 300 feet above the business portion of the city. The turbines work under 14 feet head, each wheel developing 195 effective horse-power. The power of the fifth wheel is utilized for electric lighting. The turbines are placed in substantial iron flumes, the whole mounted on solid masonry and steel I beams. The harness which supports the driving machinery is of the same construction, with iron bridgetrees. The driving gears are wood and iron machine-dressed teeth. The pumps are anchored directly on the stone foundation. The water is supplied to the turbines by one feed pipe, connected with the flumes in which the turbines are placed with branch pipes. The branch pipes are supplied with gate-valves, so that the water can be shut off from the water wheels when occasion may require. The entire outfit, being stone and iron, is very durable.

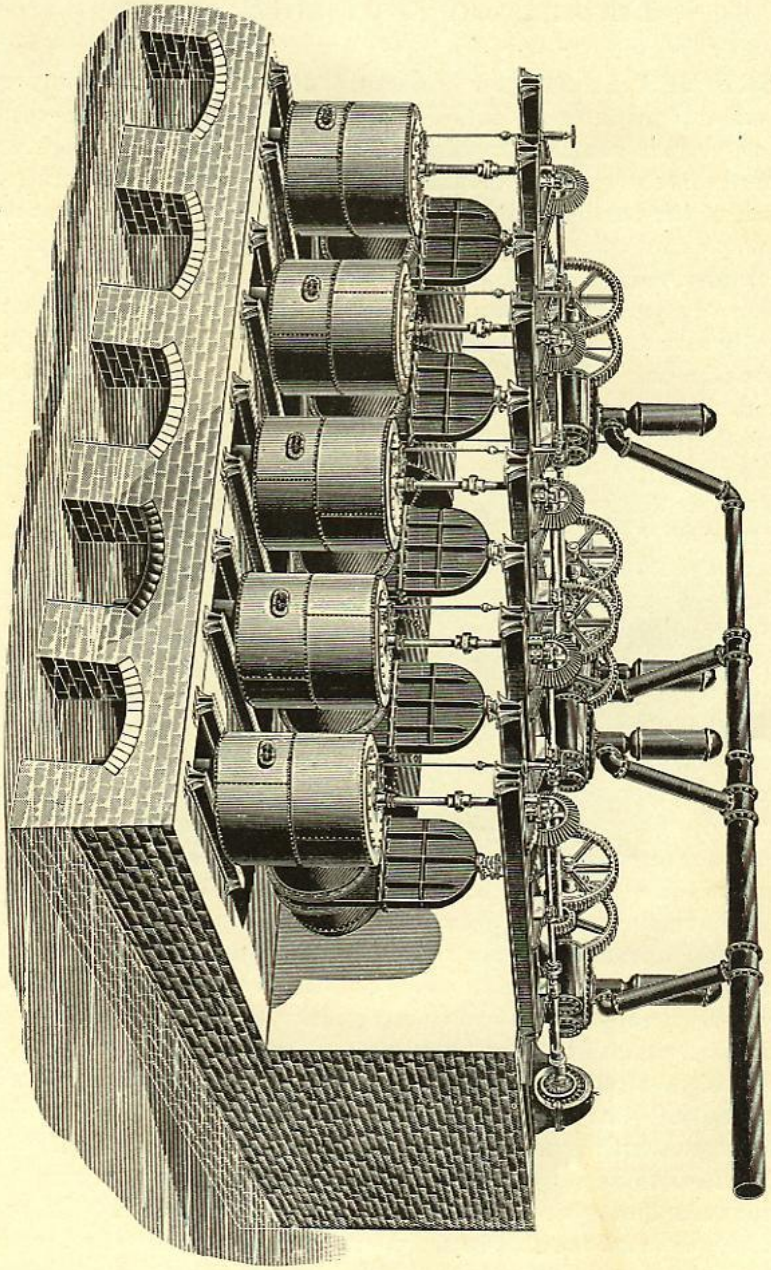


FIG. 17.

Turbines on Horizontal Shafts

TURBINES mounted on horizontal shafts afford many important advantages in some locations and conditions over wheels running on vertical shafts. Turbines on upright shafts, under high heads, are more likely to give trouble than when placed horizontally, on account of the burning out of their steps, which have to support the weight of the wheels, upright shafts and gears. When mounted horizontally, the upright shafts, driving-gears and harness are obviated. The loss of power by transmission through gears, which is considerable, is wholly saved. Turbines can be placed either singly or in pairs; but the use of a pair of wheels of the same size on a horizontal shaft is more desirable, where circumstances permit, as the pressure of the head is thereby equalized.

The placing of wheels in this manner is much preferable in certain locations, as the form and arrangement of the flume, supply pipe and draft tube are made to conform to the location, thereby saving large expenditures.

Turbines on horizontal shafts are very desirable for driving any kind of machinery which can be driven by coupling direct to the water-wheel shaft, as is done with wood-pulp grinders, pumps, electric generators, etc.

Turbines placed horizontally are above the water line, and accessible without going into the water—which, however, is also the case with vertical wheels placed in flumes having draft-tubes extending into the tail-water. They can be placed in a well-lighted, airy wheel-house, the same as a steam engine; and if the stuffing-boxes through which the shafts pass are given proper attention, there will not be any leaking.

We have furnished a great many outfits similar to the following engravings reproduced from photographs of the plants in operation, and are prepared to furnish additional information in regard to the placing of wheels to conform to any particular location, and to furnish special designs to suit peculiar locations and conditions.

Fig. 18 illustrates the least expensive manner of placing a turbine horizontally. The wheel-case is seated and bolted to a cast-iron quarter-turn which is bolted to the floor of the flume through its bottom flange and also through the vertical foot which forms a part of the quarter-turn and gives it a rigid setting in the flume. There is a concave, step and thimble in the neck of the quarter-turn for taking up the end thrust of the wheel-shaft. Access is had to this step for adjustment through handholes on either side, covered with plates as

shown. A manhole is also provided in the quarter-turn for getting at the wheel itself. The outfit sets in a wood flume, and both gate and wheel-shafts are provided with stuffing-boxes to prevent leakage.

This design can be varied in a number of ways. The power can be taken off from one end by a pulley as shown; or can be coupled direct; or can be taken off the opposite end in the same manner; or from both ends at once by extending the shaft. Likewise the wheel can be set in the flume and discharge through the quarter-turn and draft-tube placed on the outside.

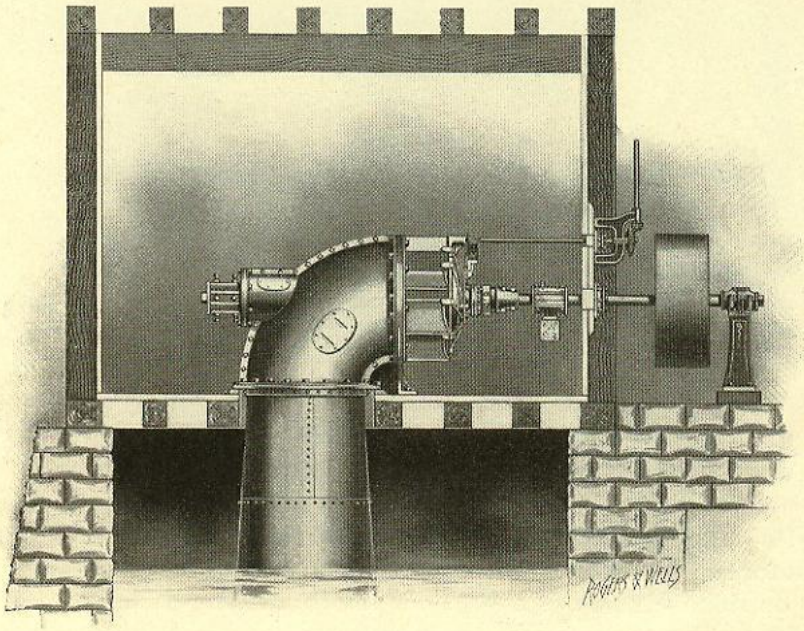


FIG. 18.

This design combines the cheapness and economy of a wood flume with all the advantages of a horizontal outfit.

Fig. 19 illustrates the least expensive manner of placing a pair of turbines horizontally in an open flume. The same design is also adapted for use in an inclosed iron flume as shown on page 60. The power may be taken off in the same varied manner as described for Fig. 18, and in addition, each wheel can be run independently if desired, in which case, each wheel is provided with separate gate-rigging, instead of combined as shown in the cut. The wheel-cases are bolted to and discharge into a wrought-iron draft-chest, conical in form. A bridgetree carrying a

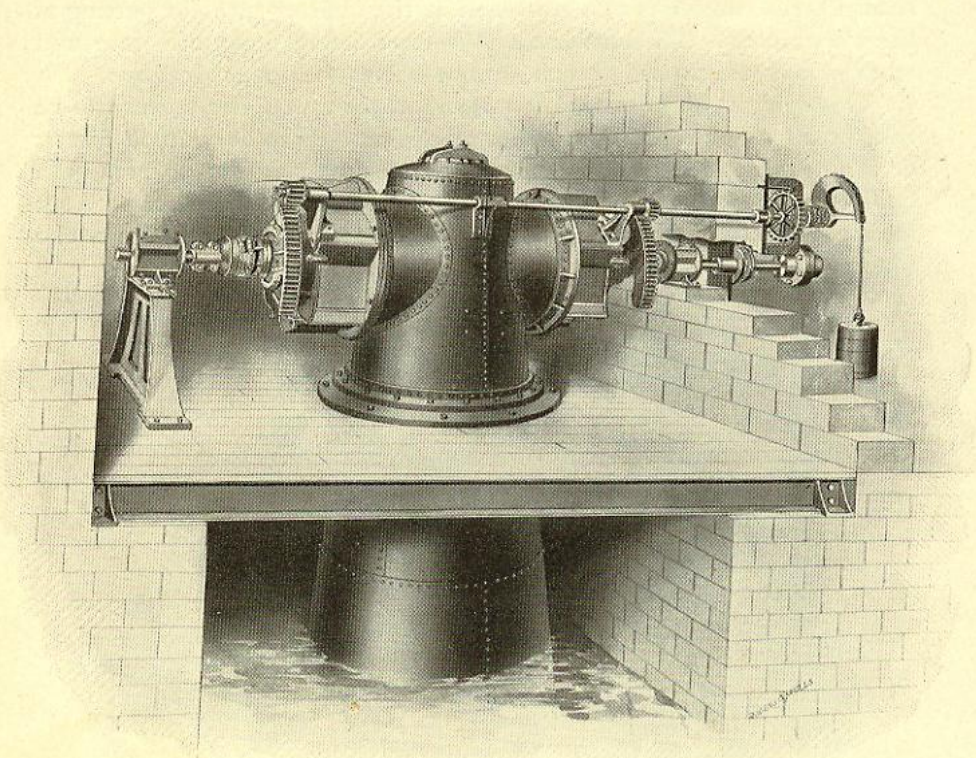


FIG. 19.

quarter-box with wood followers extends through the center of the draft-chest for supporting the wheel-shafts. On the end of the gate-shaft, that part outside the flume, is shown our improved gate-balancing device, consisting of a scroll keyed to the gate-shaft, chain and weights. By means of this mechanism, the gates of the New American are positively balanced at every stage of opening or closing, so that the work required of a governor is merely to overcome the frictional load of the shaft and gearing. The action of the New American gate is such that the greatest resistance occurs at the first stage of opening, and becomes less and less until fully open. This is due to the resistance of the water, which in the act of closing, tends to close them very rapidly. The counterweight, acting on the scroll, overcomes this resistance in opening, and serves as a check against the action of the water in closing. The scroll which is grooved to receive the chain which carries the counterweight is so designed that as it revolves with the gate-shaft, in opening, the counter-weight is suspended at a constantly

lessening radius from the center, giving it a constantly lessening leverage in exactly the same proportion as the resistance becomes less; and the reverse action in closing. The scroll is accurately laid out so that a uniform weight performs the work.

We have furnished many outfits of the design shown in Fig. 19, notably among which may be mentioned the Stora Kopparberg Bergslags Aktiebolag of Falun, Sweden, for whom we built nine outfits consisting of eighteen 36" Special New American Turbines equipped with balance rigs as shown in the engraving. Each pair of wheels was guaranteed to develop 1140 horse-power under forty feet head. An efficiency of eighty per cent was also guaranteed, same to be determined by test at Holyoke, the makers to pay all costs of the test if the efficiency was not attained, or if attained, the purchasers to pay all costs and accept the wheels.

The Stora Kopparberg Co. designated the Morgan Construction Co. of Worcester, Mass., to represent them in inspecting the work and conducting the test. At the time of making this contract, no test of the 36-inch wheel had been made, and while no doubt was entertained as to the result, to make assurance doubly sure, the first wheel as soon as completed was sent to Holyoke and tested. The result more than fulfilled our expectations. The highest percentage obtained was 86.36% and an average of 83.91% from whole to five-eighths water. The performance of this wheel, both in efficiency and power, is entirely unprecedented in the history of water-wheel testing.

The result was made known both to the Stora Kopparberg Co. and to the Morgan Construction Co. The latter passed on the work when it reached completion, carefully examined the report of the test, and advised that in view of the very large margin over what had been guaranteed they would recommend the acceptance of the wheels without the test provided for in the contract. Acting on this assurance, the entire work was boxed and forwarded to New York for shipment, but before being transferred to steamer, a cablegram was received by the Morgan Construction Co., instructing them to test one of the wheels as originally intended. They accordingly wired us for a list of all the boxes containing wheels, which being promptly furnished, they then wired us to instruct New York forwarding agents to ship box "thirty-two" to Holyoke. This was done. The selection was an entirely arbitrary one. The test was carried out under the observation of the Morgan Construction Co. only; no representative of our company being present.

We were especially glad of this opportunity for demonstrating the precise uniformity of construction of all New American wheels. The

reports of both tests are given in full on pages 38 and 39. The highest percentage obtained in the test conducted by the Morgan Construction Company was 86.76% and the average from whole to five-eighths water, 84.32%.

These wheels are being used to drive the grinders and other machinery of the new pulp mill recently erected by this company.

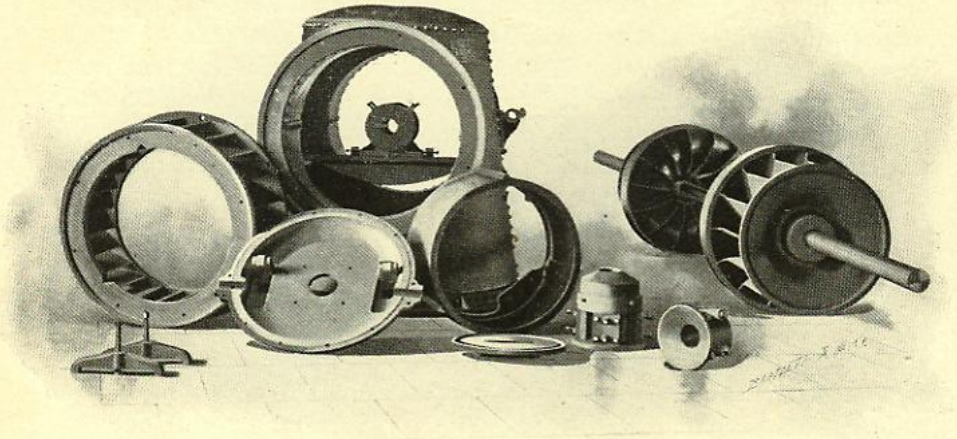


FIG. 20.

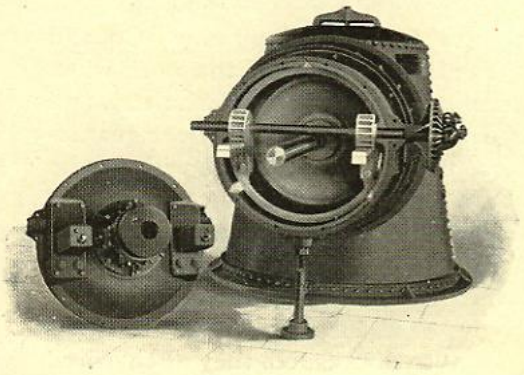


FIG. 21.

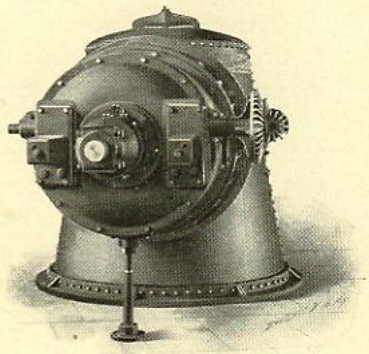


FIG. 22.

Fig. 23 represents the same type of outfit just described, but equipped with the cylinder-gate New American. On this page are additional cuts showing in detail the entire construction of such an outfit as well as the construction of the cylinder-gate wheel, a description of which may be found on pages 13 and 14.

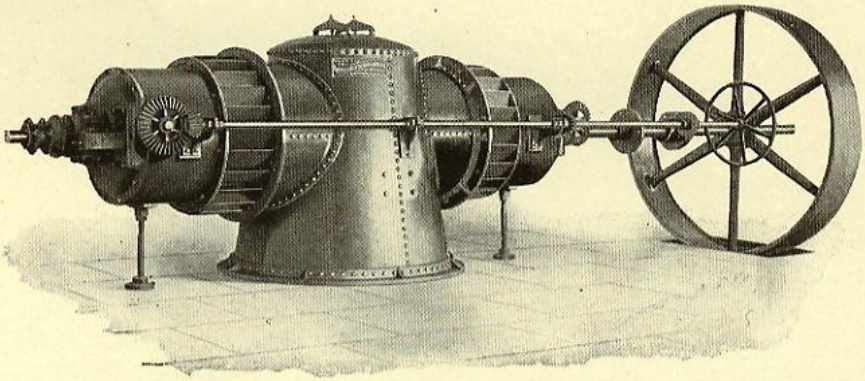


FIG. 23.

Fig. 24 shows a pair of wheels mounted in the same manner, set in a stone flume and driving by direct connection one of our Dayton Wood Pulp Grinders. Where sufficient power is available, an entire line of grinders can be thus driven by one pair of wheels, setting the grinders tandem, thus doing away with all unnecessary power connections, making a simple and economical arrangement.

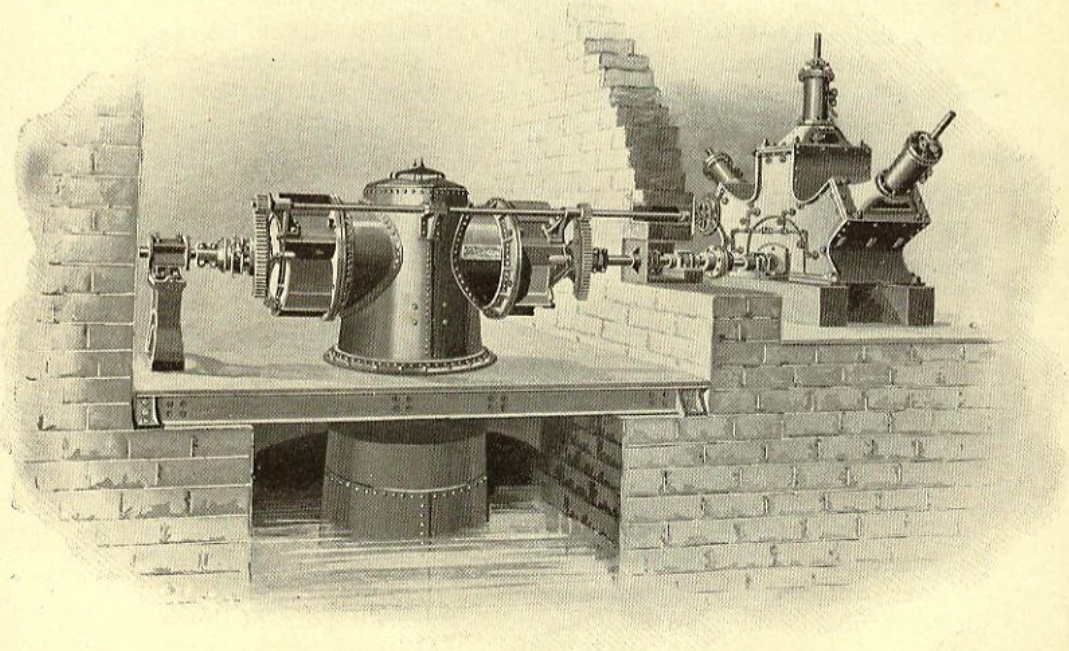


FIG. 24.

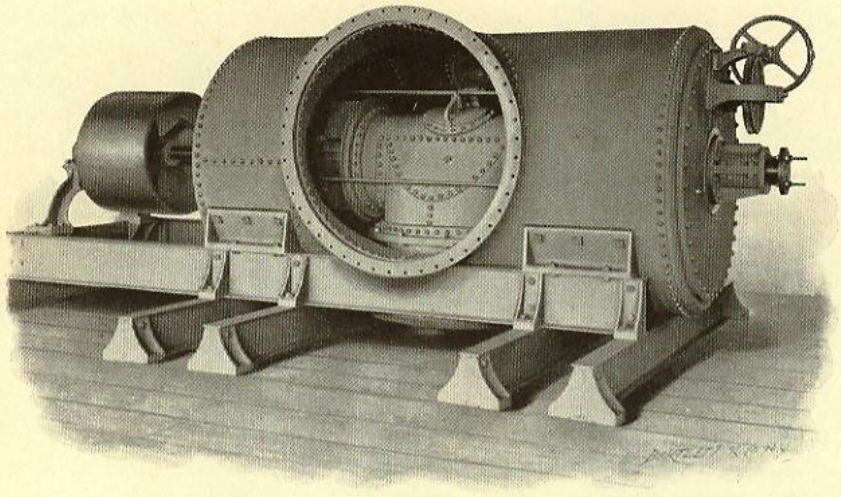


FIG. 25.

The design illustrated in Fig. 25 represents the same manner of mounting a pair of wheels on a draft-chest, with the addition of an outer encasing iron flume, making an outfit complete with mouthpiece ready to connect up to supply-pipe, and with beams, anchor-brackets, etc., ready to set on foundations. The outfit is entirely self-contained, with stand and bearing carried directly on the foundation beams, and driving pulley for transmitting the power. The outfit is substantially built and has the virtue of being the most compact arrangement that can be designed for a pair of wheels, a desirable feature where space is limited.

PENN YAN, N. Y., April 27, 1899.

The Dayton Globe Iron Works Co., Dayton, Ohio :

GENTLEMEN : The wheels reached Cascade in good order day before yesterday. Please find enclosed settlement for the same, which I send you with great pleasure. The work does you great credit. I wish to commend you for the business-like manner in which you have conducted this contract from your first overture. Contrary to some, your first endeavor was to make a careful study of the situation and requirements and adapt your plans to what was wanted. This made the business easy for both of us, for in my case I deem it of more importance to be right than to be "off-hand," and I did not take with those that thought to do business with me on the jump. I wish particularly to thank you for your uniform courtesy and careful attention to every suggestion I could make to you, and the clear earnestness you have shown to carry out my every wish. Such attention merits the success that in a business way I know must be yours. Very truly yours,

EDWARD R. TAYLOR.

The two engravings, Figures No. 26 and 27, illustrate an outfit furnished by us in 1896 to the Boston and Montana Consolidated Copper and Silver Mining Company, of Great Falls, Montana, being probably the largest and most powerful pair of horizontal turbines, for the head of water under which they operate, that have ever been built.

The photographs were taken in the power house at Great Falls, one representing the erecting crew at work on the mammoth flume, and the other the turbine outfit completed, coupled by means of flexible couplings to the Westinghouse generators.

The turbines are of the latest design, 57 inches in diameter, and under the head of 50 feet will develop 3,945.6 horse-power.

They are mounted on a cast-iron draft-chest and discharge centrally through a draft-tube, 10 feet in diameter, incased in an iron flume 14 feet 4 inches in diameter, 32 feet 6 inches long, made of half-inch tank steel, with cast-iron heads. The flume is mounted on two pairs of double I beams, 20 inches deep, 38 feet long, and receives the water through two intake pipes, 10 feet in diameter, entering the flume from the back opposite each wheel.

The shaft in the wheels is 10 inches in diameter, 42 feet 2 inches long, made in two sections, weighing over five tons. The clamp coupling which connects these two sections of shafting in the center of the draft-chest, weighs considerably more than one ton. There are stands at each end of flume weighing 8,000 pounds each, carrying the journal boxes for the shaft. The two turbines, with their complete outfits, weigh approximately 250,000 pounds.

These turbines operate two Westinghouse electric generators used for electrolytic refining. They are direct-coupled to each end of the shaft, which runs from 144 to 160 revolutions per minute. The varying revolutions are required in order to increase or diminish the current as conditions may require.

A portion of the power is also utilized for driving an arc-light dynamo and two 50-h. p. exciters, and is transmitted from the wheel-shaft to dynamo by means of a 20-inch double leather belt, and there still remains a surplus power for future contingencies.

These wheels were sold under a guaranteed average efficiency of 80 per cent from three-quarter to whole gate and to develop 2800 h. p. under 40 feet head. When tested at Holyoke, as per contract, they exceeded the guaranty both in horse-power and efficiency, showing an average efficiency from three-quarters to whole gate, inclusive, of 81¼ per cent, certainly a remarkable performance in view of the fact that they were the first wheels of this diameter built by us.

On page 37, are shown synopses of the tests of these two wheels, made by the Holyoke engineers, giving the horse-power and efficiency of the wheels at different stages of gate.

In consequence of the great strain on a turbine, working under a fifty-foot head, the buckets of the wheels were necessarily made very thick. Had they been made the ordinary thickness, the percentage of

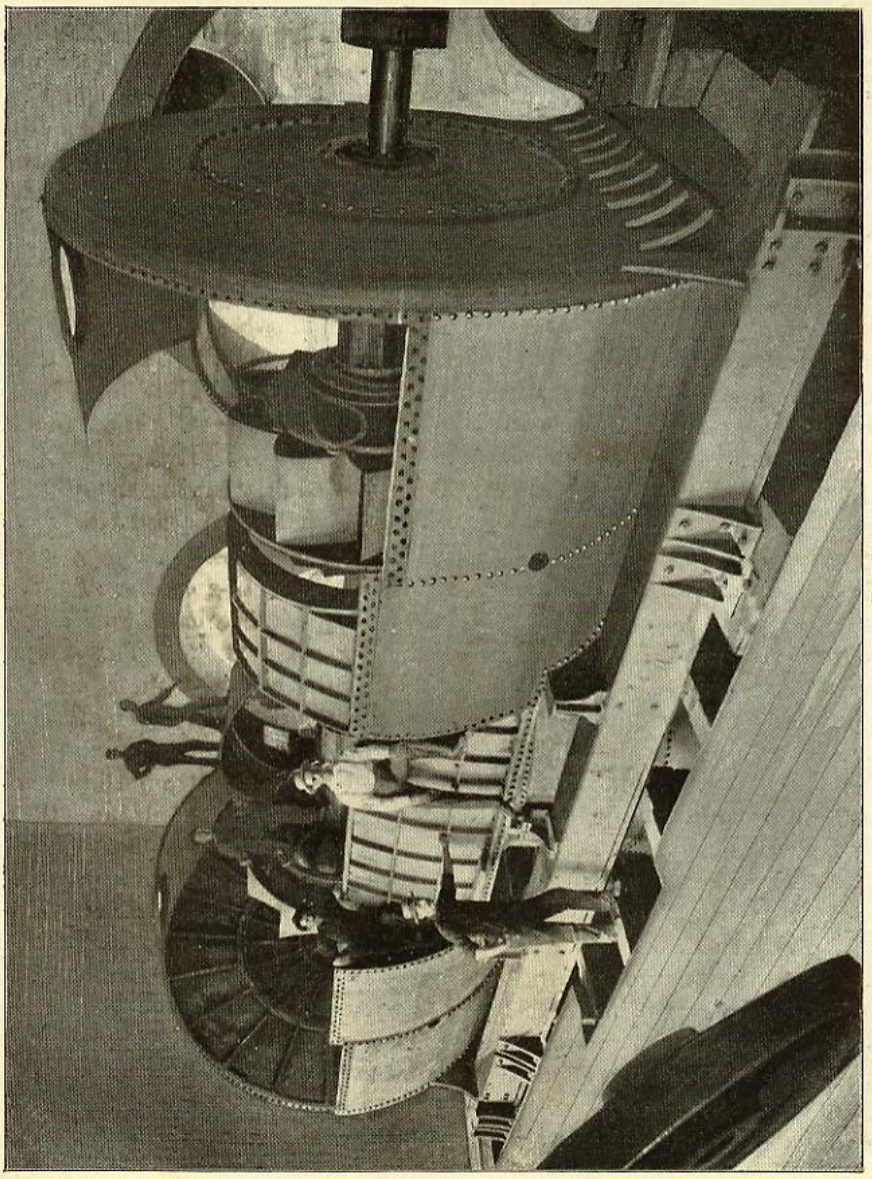


FIG. 26.

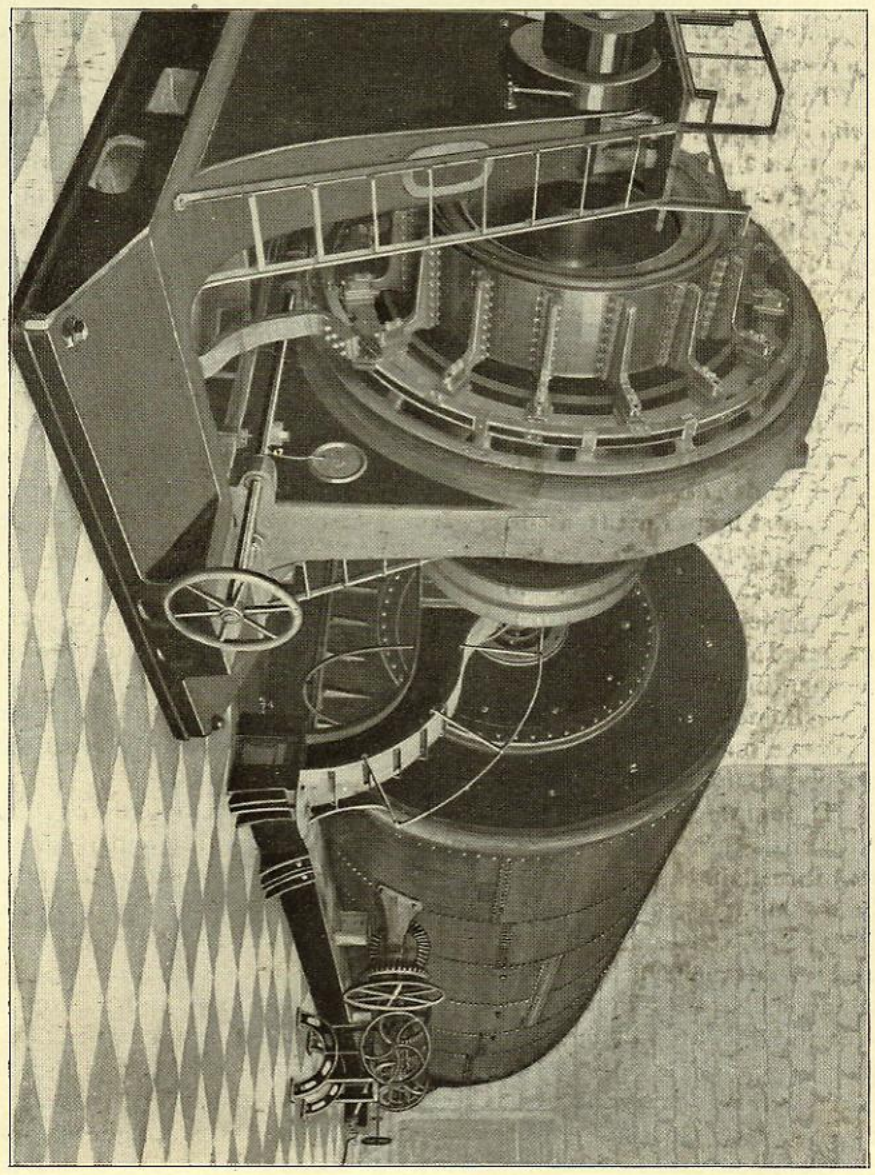


FIG. 27.

useful effect would have been increased to at least 83½ to 84 per cent. This was the judgment of a number of engineers who made an examination of the turbines. They were tested with the ordinary straight cylinder below the wheel. Flaring draft-tubes or diffusers would have increased the percentage.

The plant was erected under our superintendence and operated for a sufficient length of time to demonstrate the mechanical perfection of the work and the fulfillment of the guarantees. Since it was turned over to the purchasers, we have never been called upon to furnish a single item of repairs.

In Figures 28 and 29 are shown the plan and cross-section of power-house and penstocks of the Helena Water and Electric Power Co., located at Canyon Ferry, Montana, on the Missouri river, the hydraulic equipment of which was designed and furnished by our company.

The engravings very clearly show the character, extent and details of this magnificent installation. The plan provides for ten pairs of wheels.

At present it consists of two single 25-inch special New Americans and four pairs of 42-inch wheels. The 25-inch wheels are mounted in horizontal flumes with cast-iron quarter-turn discharge and are used for driving the exciters. The water is admitted or shut off by large gate-valves attached to the supply connections of the flumes.

The four pairs 42-inch specials drive the generators. They are mounted horizontally on cast-iron draft-chests, quarter-turn form, discharging centrally, through one draft-tube, the whole incased in steel flumes 12 feet diameter, 21 feet 4 inches long, with cast-iron heads on one end, and the other end riveted to the cone connections leading to the steel supply pipe.

These large flumes are mounted on steel girders, bolted together with cross-ties. The wheels are supplied with safety steps to prevent end thrust, and there are combined follower and stuffing-boxes with brass glands attached to the cast-iron flume heads. There are also follower-boxes supported by columns which carry the other ends of wheel-shafts. The shafting in the wheels is in two sections, one of which is 6½ inches in diameter, 12 feet 9 inches long, and the other section 8 inches in diameter and 14 feet 6 inches long, coupled by a pair of compression couplings inside the draft-chest. The 8-inch shafts have to transmit the power of both wheels and are directly connected by means of a flexible coupling to the 900 h. p. generators.

Each pair of 42-inch Special New American turbines is guaranteed to develop 930 h. p. under 28 feet actual working head at a speed of 162 revolutions per minute.

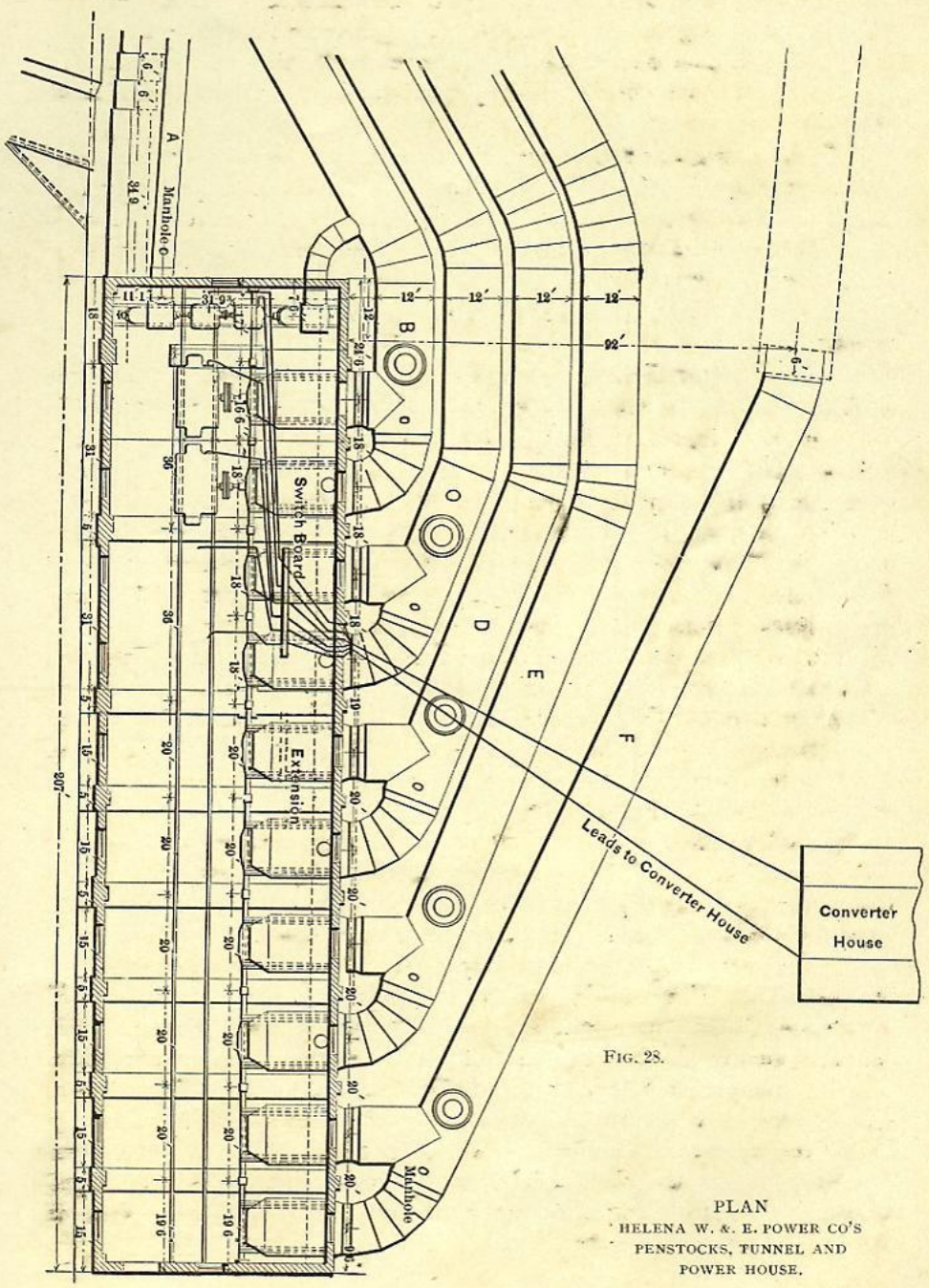


FIG. 28.

PLAN
HELENA W. & E. POWER CO'S
PENSTOCKS, TUNNEL AND
POWER HOUSE.

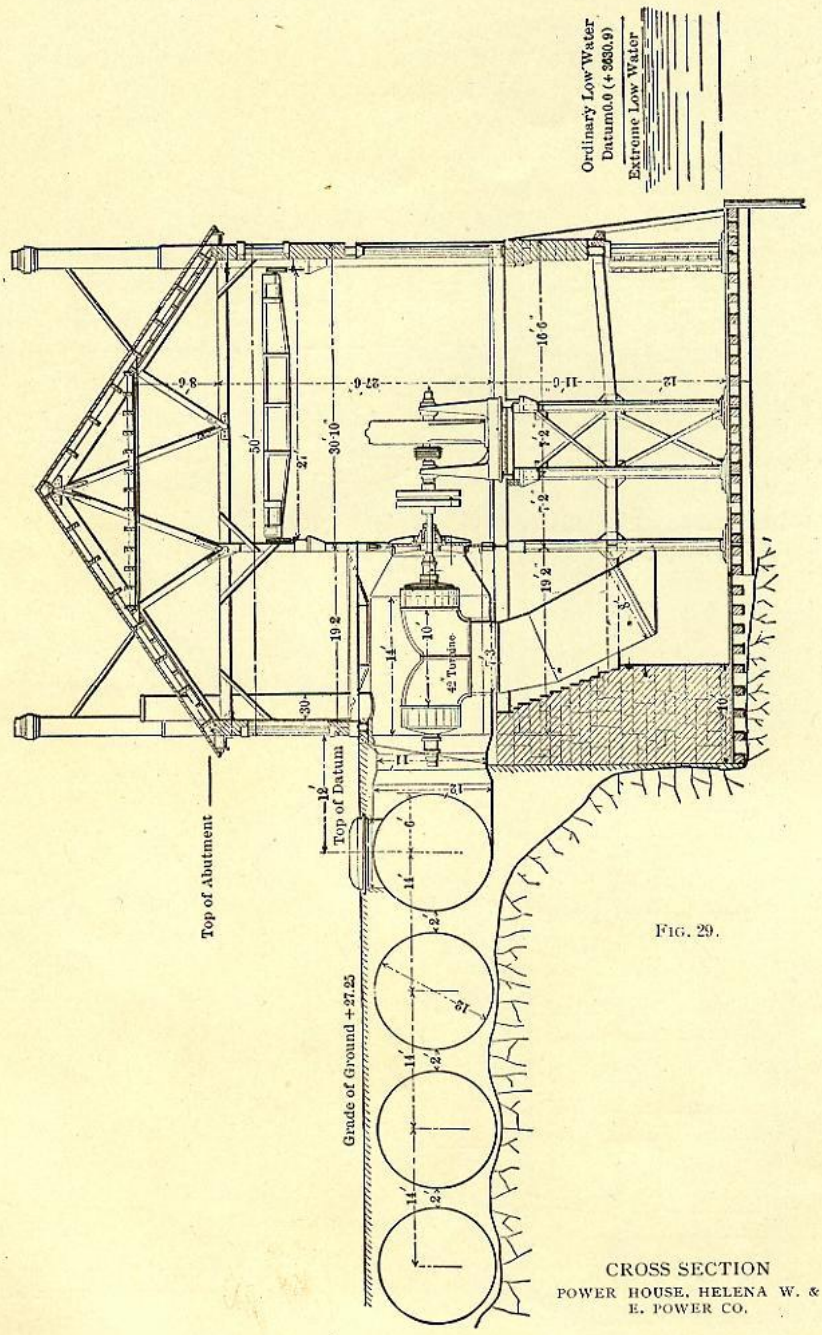


FIG. 29.

CROSS SECTION
POWER HOUSE, HELENA W. & E. POWER CO.

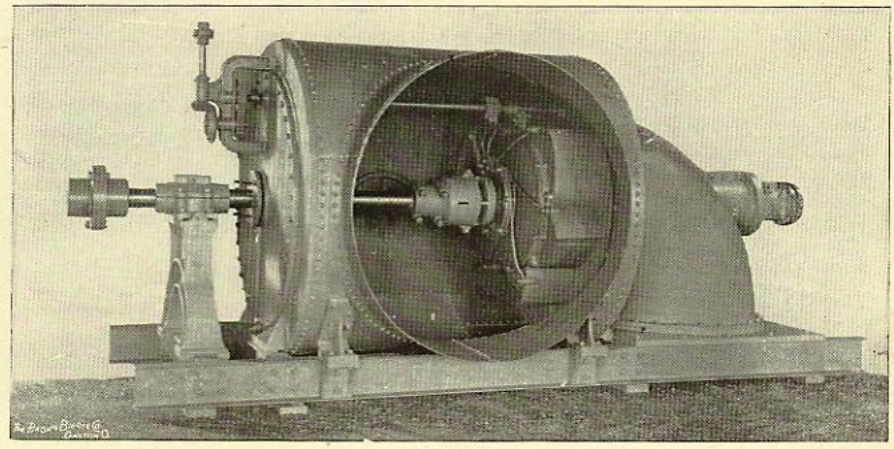


FIG. 30.

The two designs shown on this page are representative outfits of single horizontal wheels, the first made to drive by direct connection, the second by belt. Both are entirely self-contained, resting on a foundation of steel I beams and cast-iron cross-girders bolted together. A mouth-piece extends from the side of the flume to which the supply-pipe can be riveted. The head end consists of a cast-iron ring to which the boiler iron is riveted, and a cover plate, the latter of sufficient diameter to permit the entire wheel being taken out through the opening. The draft-tube plate, which carries the draft-tube and also supports the quarter-turn, is rectangular in shape, heavily ribbed crosswise, and rests square on the beams on all four sides. A safety-step on the dome of the wheel and another in the neck of the quarter-turn, take care of all end-thrust of the shaft. The whole construction is characterized by the greatest strength and rigidity.

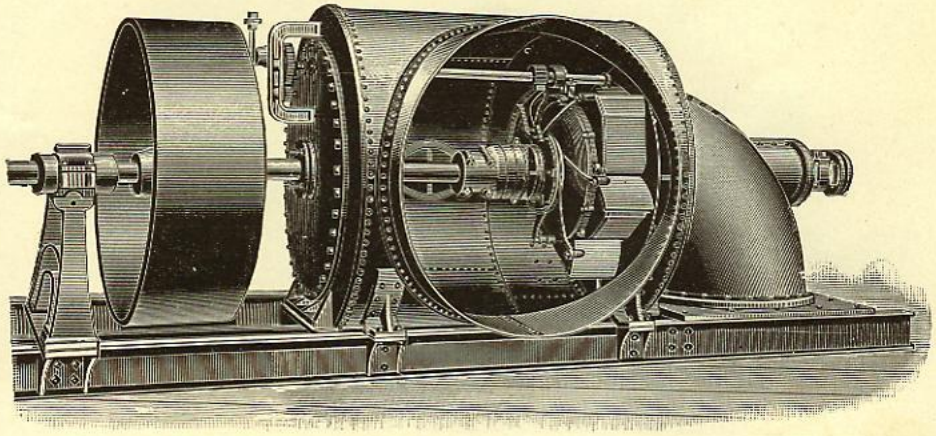


FIG. 31.

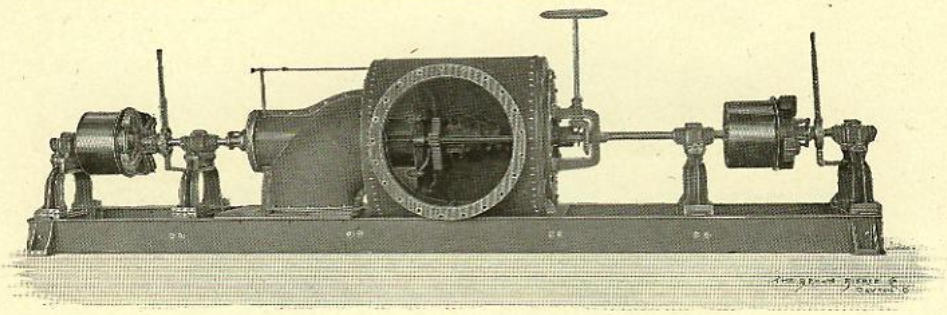


FIG. 32.

Fig. 32 is the same construction as just described. The power is taken off both ends, however, and is transmitted by friction clutch-pulleys. This outfit was furnished the Remington Arms Company, Ilion, N. Y. Fig. 33 is the same in all respects as Fig. 32 with the addition of a gate valve attached to the mouth-piece for admitting and shutting off the water to the flume. This outfit with a 30-inch wheel was furnished the High Falls Pulp Company, Chateaugay, N. Y., and is operating under 100 feet head.

Two outfits with 25-inch wheels of the same design were also furnished to the Helena Water and Electric Power Company, referred to in the description of their plant, page 64.

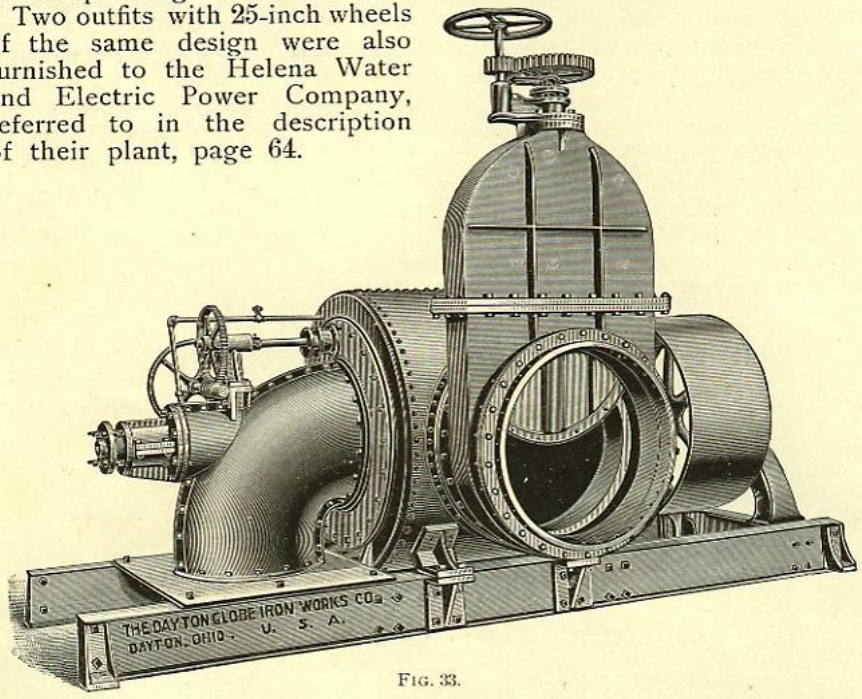


FIG. 33.

The two illustrations opposite represent the Cylinder Gate New American, similarly mounted, including in addition foundations, draft-tube, etc. These outfits represent the highest type of horizontal

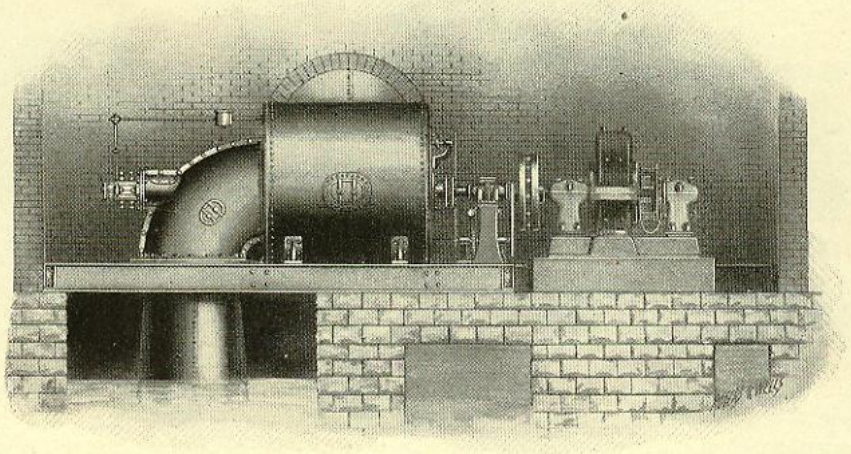


FIG. 34.

turbine construction. The draft-tube is made flaring, giving the freest discharge from the wheel. The driving pulley is carried between two journal-box stands, preventing any lateral wear on the stuffing-box in the head of flume. Cast-iron cross-beams are located under each stand, under both ends of the flume, and both ends of draft-tube plate. Handholes are provided on each side of neck of quarter-turn to permit access to the step for adjustment. The bearing on end of quarter-turn is a combined follower and stuffing-box with brass gland. Water is supplied from the flume to the followers and step for lubrication, and is kept free of debris by running through a screen-pot.

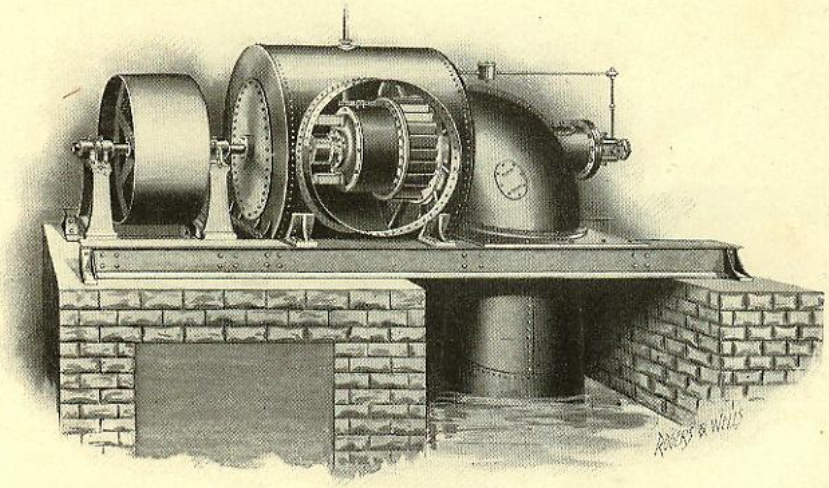


FIG. 35.

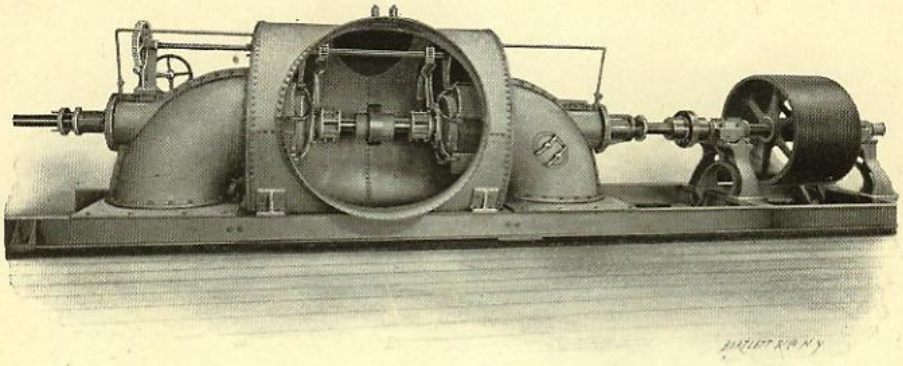


FIG. 36

A pair of turbines mounted on one shaft in a horizontal flume, with double quarter-turn discharge, is probably the best-balanced and strongest construction that can be designed for a horizontal outfit. The end-thrust of the pair of wheels is entirely equalized, and the pressure is equally distributed throughout the flume, quarter-turns, landing plate and foundation beams, as can readily be seen by a little study of the design. These advantages are further heightened by the most careful workmanship in fitting up. The flume heads are faced off true and the flume set up perfectly plumb with the bed. The landing plates are planed and bolted to the beams so as to be perfectly square with the flume-heads, and both flanges of the quarter-turns faced square with each other, so that all parts fit accurately and when bolted together make the most rigid construction possible.

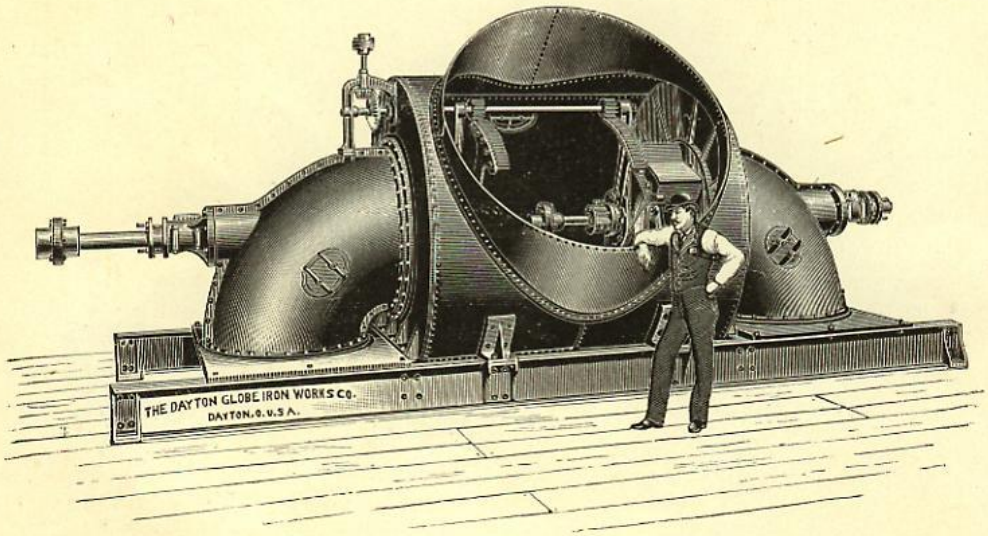


FIG .37.

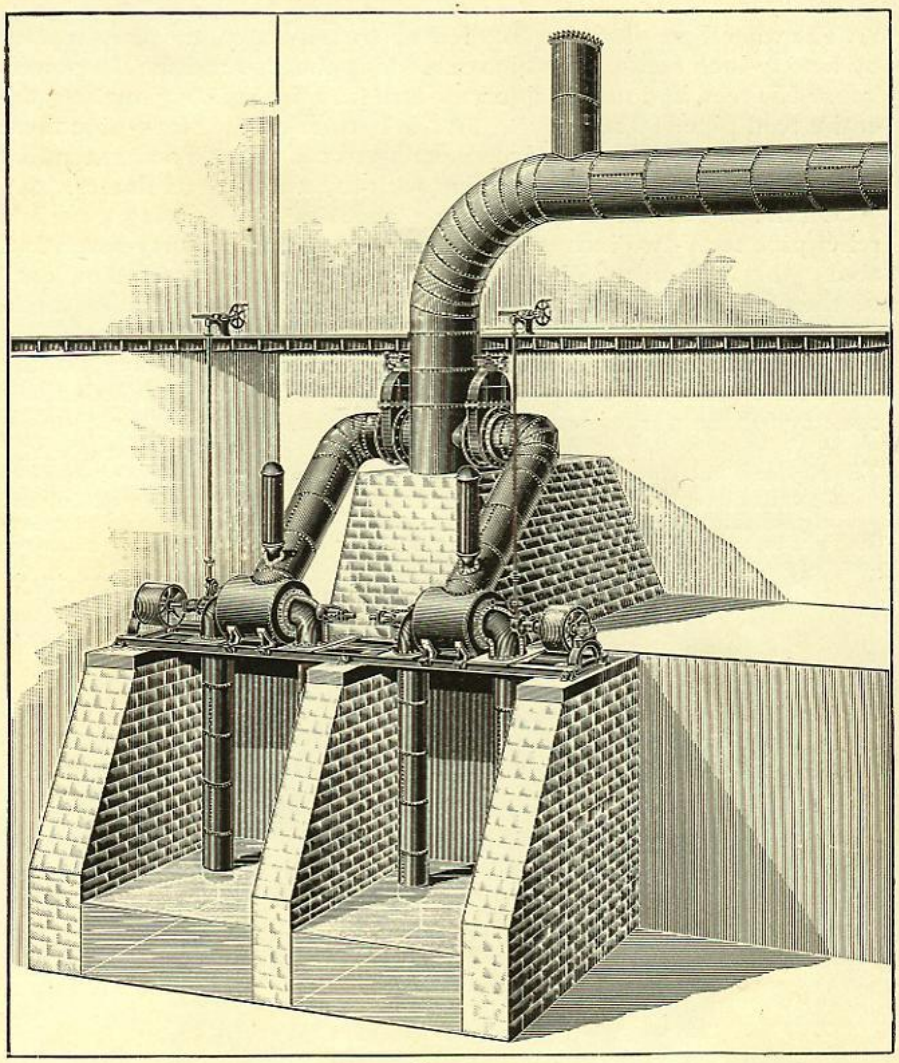


FIG. 38.

Fig. 38 represents two pair of thirty-inch small-issue wheels of special design, each pair in a horizontal iron flume, mounted on steel I beams, designed and built for the Ithaca Street Railway Co., of Ithaca, N. Y. These wheels are operating under ninety feet head, each pair developing 400 effective horse-power, one pair furnishing power for the electric street railway, and the other pair driving the electric light plant of this company. The power is transmitted to the dynamos by means of manila rope.

The wheels are placed twenty feet above tail-water, and are supplied by a sixty-inch feed-pipe, which extends up the stream from the power-house 550 feet, and makes a quarter turn into the building, making the entire feed-pipe 600 feet long. At the bottom of the stand-pipe there are two nozzles, a feed-pipe connecting to each nozzle and extending down about twenty feet, connecting with the water-wheel flumes.

On the top of the large feed-pipe inside of the building there is a relief pipe forty-two inches in diameter, extending up forty-seven feet above the feed-pipe. There is also an air-chamber erected on each of the flumes. These air-chambers are constantly kept full of air to relieve the concussion when the water is shut off from the wheels. In fact, the whole arrangement is perfect and complete even to the minutest details, and the plant is one of the finest ever installed in this country for the purpose of generating electricity.

ITHACA, N. Y.

The Dayton Globe Iron Works Co., Dayton, Ohio:

GENTLEMEN: Replying to your inquiry, we beg to say that we are using two pair of your thirty-inch horizontal wheels, under ninety feet head, for driving electric light and railway apparatus, with the best of satisfaction. In fact, we fail to see how the plant could be improved upon in any way. Yours very truly,

ITHACA STREET RAILWAY CO.
D. THOMSON, Gen'l Supt.

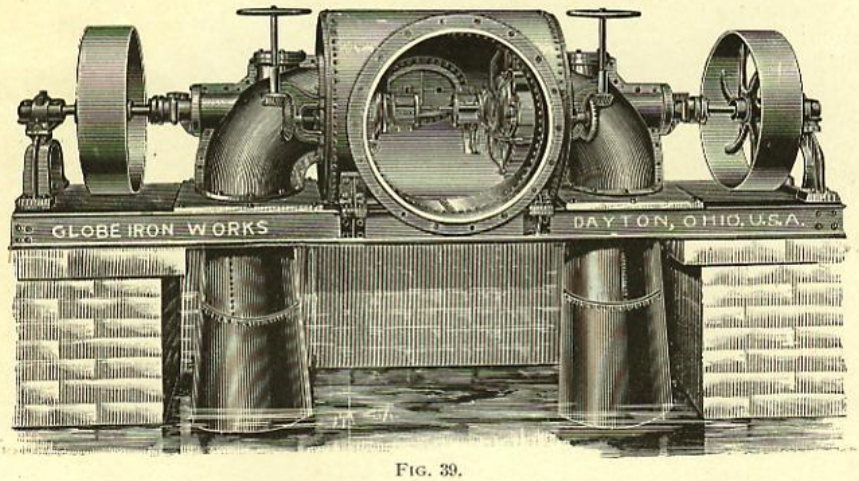


FIG. 39.

Fig. 39 shows a pair of 16-inch New American Turbines furnished the Hennepin Paper Co., of Minneapolis, Minnesota, to drive a pair of paper machines. They are mounted in the same case, and supplied with water from the same supply pipe, but are independent of each other. Each water-wheel has its own shaft, which are not coupled in the case, although they are in line with each other. Also, each wheel has its own gate-gearing, by which it may be started independently of the other. In this way two water-wheels can be erected in one case at a less expense than if they are placed in different cases, and supplied from different feeders. The case is constructed with cast-iron quarter turns and heads and wrought-iron sides, and rests on steel I beams.

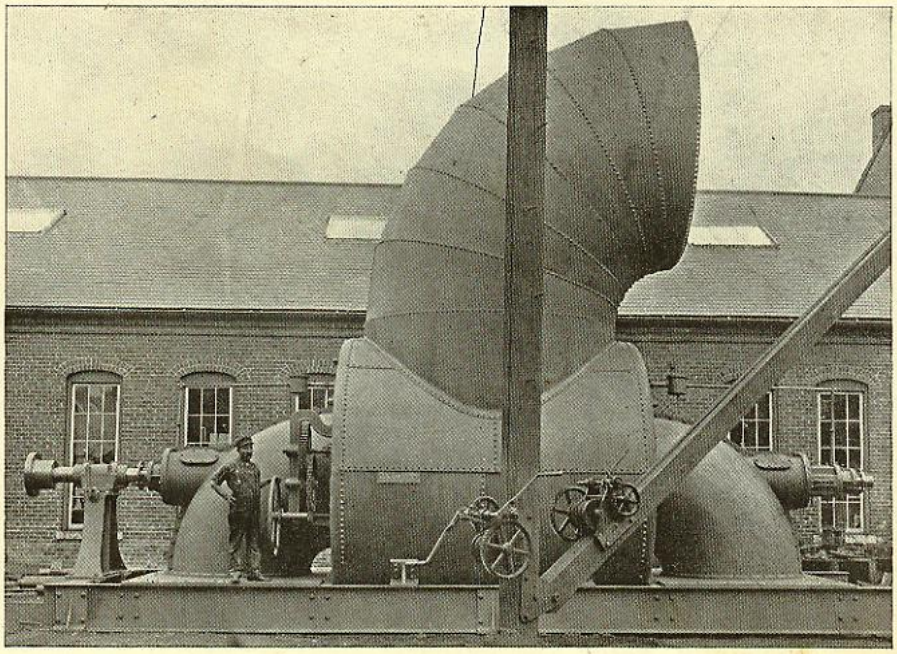


FIG. 40.

In the latter part of 1898 we furnished The Northwest Paper Company, the entire turbine installation for their new Mill at Cloquet, Minn. The work consisted of two pairs of 36-inch Specials in double horizontal flumes as shown in Fig. 40 and two single 36-inch Specials, to one of which was connected a single 16-inch Special as shown in cut, Fig. 41.

Fig. 40 represents one of the double outfits as it appeared, erected complete, in our Works. The flume is 11 feet in diameter, 11 feet 6 inches long, made of ⅜-inch steel plate. The feeder-pipe is 10 feet in diameter, entering the flume at the top by a quarter-turn. The water discharges through quarter-turns 60 inches in diameter. The bed is made up of 20-inch steel I beams and cast-iron cross-ties.

Fig. 41 represents one of the single outfits to which is connected the single 16-inch wheel. The flume is 9 feet in diameter, 9 feet 3 inches long, made of ⅜-inch steel plate and rests on 15-inch I beams. The feeder-pipe is 7 feet 9 inches in diameter, large enough to supply both flumes. The connection to the small flume is through a 36-inch feed-pipe, to which is attached a gate-valve for admitting and shutting off the water. The entire work was erected complete in our Works, including fitting on feeder-pipes, then taken apart and shipped in knock-down form and re-erected at destination under our superintendence. The large flumes being too large to ship entire, were made in halves.

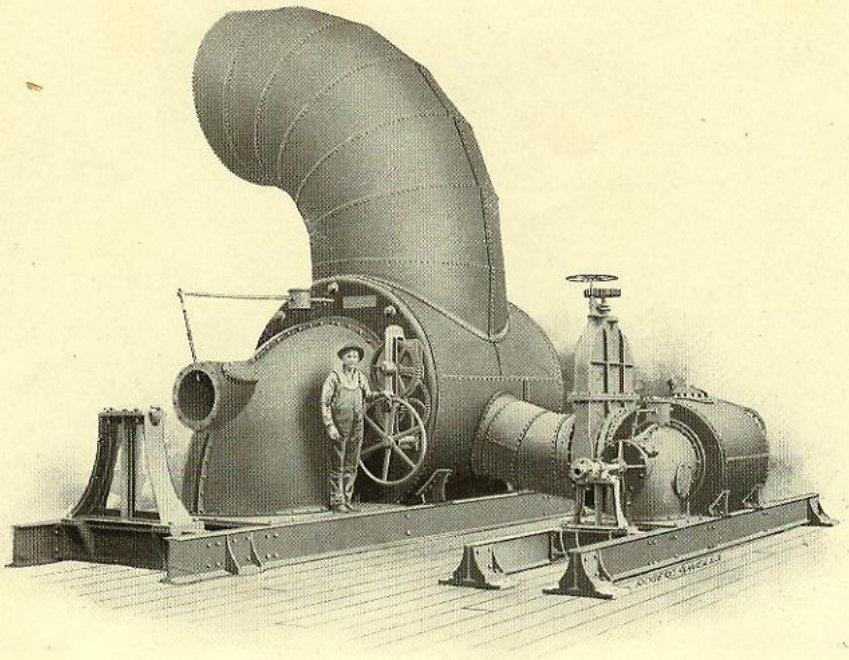


FIG. 41.

Fig. 42 is from a photograph taken of all five outfits when erected complete in the Mill. Each 36-inch wheel is guaranteed to develop 515 horse-power, under a head of 35 feet, this guarantee being made and accepted on the official report of the test of the 36-inch Special New American as given on page 38. The high standard of the New American as shown by these tests, and its superiority over other turbines, decided the Northwest Paper Company in its selection, as it has many other discriminating buyers who appreciate a wheel of merit rather than one of questionable value. To the report of the Holyoke Water Power Company, which is incontrovertible, we are pleased to add the testimonial of the manager of The Northwest Paper Company as to their performance in practical operation.

CLOQUET, MINN., Aug. 21, 1899.

The Dayton Globe Iron Works Co., Dayton, Ohio:

DEAR SIRS:—We are very glad to state that the six 36-inch Special New American Water-wheels, and the one 16-inch Special New American Water-wheel, together with the intake pipes, flumes and draft-tubes, installed by you in our plant last winter, are all working to our satisfaction.

We have just placed an order with your Mr. W. M. Mills for a duplicate of the entire outfit. We are operating these wheels under a 36-foot head, and under conditions requiring extra heavy construction of our water-wheel equipment.

Yours, etc.,

C. I. MCNAIR, Mgr. NORTHWEST PAPER CO.

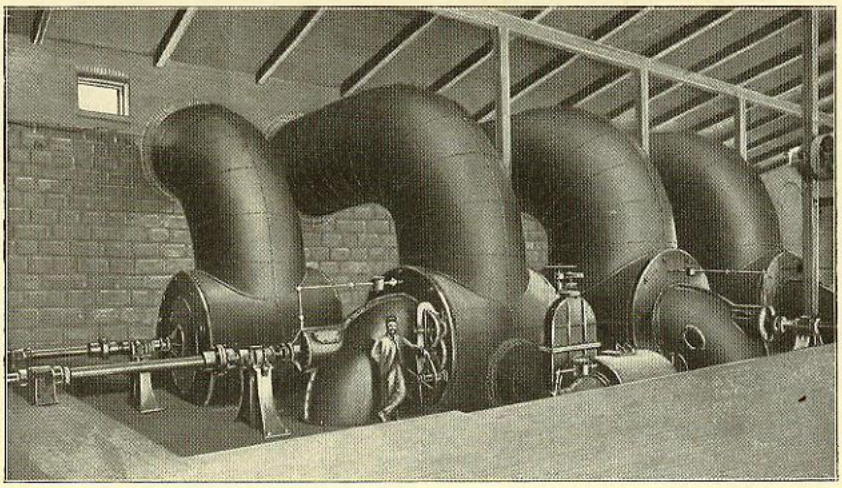


FIG. 42.

In keeping with the high merit of the wheels, they were given a setting of the highest excellence in design and construction. So well pleased was the Company with the entire work in every respect, that we were given a second order, without competition, for three additional outfits as shown in Fig. 40. The Mill is a model of its kind throughout, designed by C. B. Pride, of Appleton, Wis., and erected under his personal supervision. Regarding the turbine installation, Mr. Pride wrote us:

"I have a letter today from Cloquet, Minn., in which they state that they are running and making pulp and paper. Everything is going comparatively well for a new plant. I have heard quite a number of compliments on the installation and the arrangement and the general lay-out of the water-wheel department at Cloquet, and I am positive that it will get more business for you in that vicinity sooner or later."

And again:

"I have just returned from a few days' trip to Cloquet, Minn. Spent two days in the Mill there and found everything operating very nicely so far as I could see. Your water-wheels and installation are simply immense and work to perfection, not a jar or vibration throughout the plant. In fact it is the best arrangement I have ever installed in any mill. I simply had my plans carried out in general and everything works nicely. When the other three sets of wheels are installed it is going to make one of the most extensive power plants in this vicinity and will be a great advertisement for you. Yours very truly,

C. B. PRIDE."

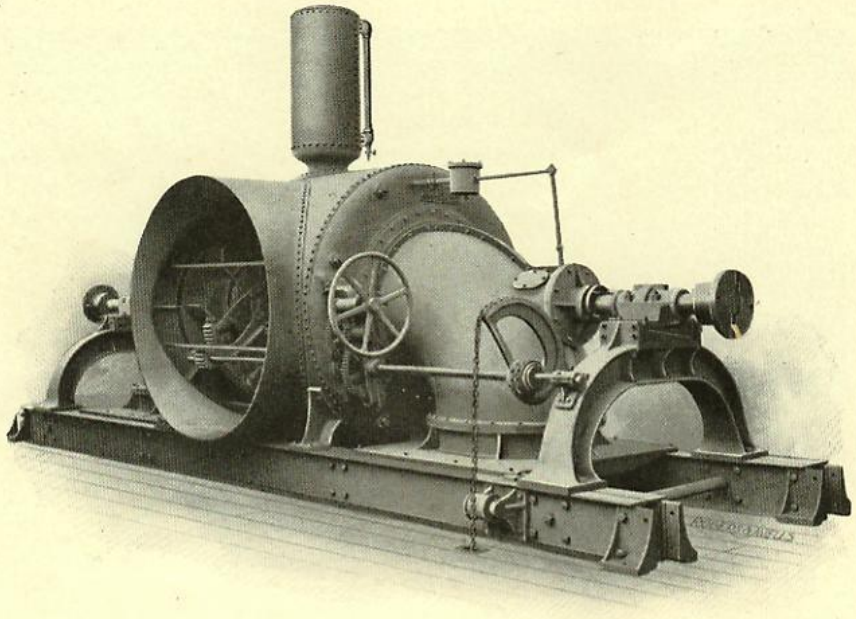


FIG. 43

The above cut represents a pair of 36-inch horizontal wheels, of special design, to develop 1,200 horse-power at a speed of 300 revolutions per minute, under 80 feet head, furnished the Hannawa Falls Water Power Co., Potsdam, N. Y. The wheels drive by direct connection two General Electric Co. generators. The design is an especially strong one throughout to meet the requirements of the high head under which they operate. The runners and wheel-gates are made of bronze. The flume is made of $\frac{3}{8}$-inch steel plate, with heavily ribbed cast-iron heads, braced at the supply-opening with four $1\frac{3}{4}$-inch stay-rods, and furnished with large air-chamber to relieve concussion. The cast-iron quarter-turns are 45 inches in diameter and are supported on cast-iron landing plates, flanged and ribbed above and below the beams. The foundation beams consist of two pairs of 15-inch steel I beams, bolted together on cast-iron separators. The bridgetrees, carrying the journal boxes, rest on the face of the beams, spanning each pair with projecting lips on each side of foot. The whole construction is characterized by the greatest strength and stiffness in all its parts.

The journal-boxes are of the most approved type of ring-oilers and are adjusted by means of wedge-blocks on top of bridgetree.

The shaft on which the gate-pinions are keyed extends through the flume-head, and is fitted with balance-scroll and weights, as described on page 56.

The New American System of Test-Tubes

THE cut on page 79 shows our method of applying Test-Tubes to Water-wheels in order to determine whether an excessive part of the fall is lost in bringing the water to the water-wheel and in carrying it away. It is a modification of the methods used in testing flumes to find the efficiency. The tubes shown in this cut can be made of iron gaspipe or india-rubber of an inside diameter of about three-eighths of an inch. Every water-wheel mounted on a horizontal shaft should be tested immediately after its erection with the draft-tube gauge C, to find whether water fills the draft-tube, and this gauge should be applied whenever it is suspected that the draft-tube is not working properly. Also, when a water-wheel frequently gives trouble by wearing out the step, the dome-gauge D will be found of great value in detecting the difficulty. The main object of the head-gauge A and the tail-gauge B is to see whether the feeder and draft-tubes are of sufficient size.

The Head-Gauge A

The principal part of this test-tube is constructed of gaspipe or of rubber. The upper section of it is of glass. It is inserted in a hole tapped into the case and the water rises in this tube to the full head due the pressure of the water in the case.

The method of using it is as follows: Open the head-gates and close the gates on the water-wheel. The water will then rise in this tube to the exact level of the water in the canal or pond. Mark or note its height. Then open the gates on the wheel. The water will drop in the glass gauge, and will show the exact pressure then being exerted on the wheel. The difference between the two records, which is the amount that the water drops, is the head lost from friction and velocity in the pipes, and from similar causes. If this loss does not exceed three inches, the feeders are well planned and proportioned. We have tested plants where this gauge showed a loss of three feet, which was excessive.

The Tail-Gauge B

The object of this tube is to show the head lost from friction of the water in the draft-tube and its quarter-turn. The lower section of this tube is made of glass. As soon as the gates are open, the water rises in the tube above the level of the tail-water, and the difference

between these two levels is the head lost in the draft tube from friction of the water. The distance from the level of the water in this tube to the level of the water in the head-gauge A is the actual head operating on the water-wheel.

When this tube is made rigid and of iron, it will be necessary to have a valve like a pump-valve at E, so that the tube will fill with water, and not allow the air to enter the draft-tube. When a rubber hose is used the lower end of the tube can be submerged in tail-race until the tube is full of water, and then the test can be made.

The Draft-Tube Gauge C

The object of this tube is to see whether the draft-tube is full of air or of water. It is constructed on the principle of the boiler gauge. The section of pipe which is on the level of the top of the wheel should be of glass, and the rest of iron, or of rubber. The upper end is inserted in the top of the draft-tube, and the lower end extends into the tail water, and is left open. The water stands in this tube at the same height that it stands in the draft-tube.

It is only necessary that the water should rise in this tube and in the draft-tube to the same height as the highest part of the water-wheel runner. If there is air in the draft-tube above this level it will have no effect upon the operation of the water-wheel.

The Dome-Gauge D

When water-wheels wear loose, so as to leave a large opening between the runner and the case, and in some new and badly designed water-wheels, where no apertures of sufficient size are left for its escape, the water which collects between the runner and the dome-shaped cover will produce a heavy pressure upon the wheel, and so will wear out the step. To find out how great this pressure is, a pipe should be inserted in the dome at a point three-eighths of the diameter of the wheel from the center of the shaft. The height the water rises in this tube above tail-water shows the pressure of this water upon the water-wheel.

Very few appreciate the load which the pressure of this water brings upon the step of a turbine. We have tried this gauge upon a badly-designed wheel, and found it to amount to three-fourths of the entire fall. In water-wheels of large size and power this pressure may amount to many tons, and accounts for many cases where steps have made trouble.

Test-Gauges

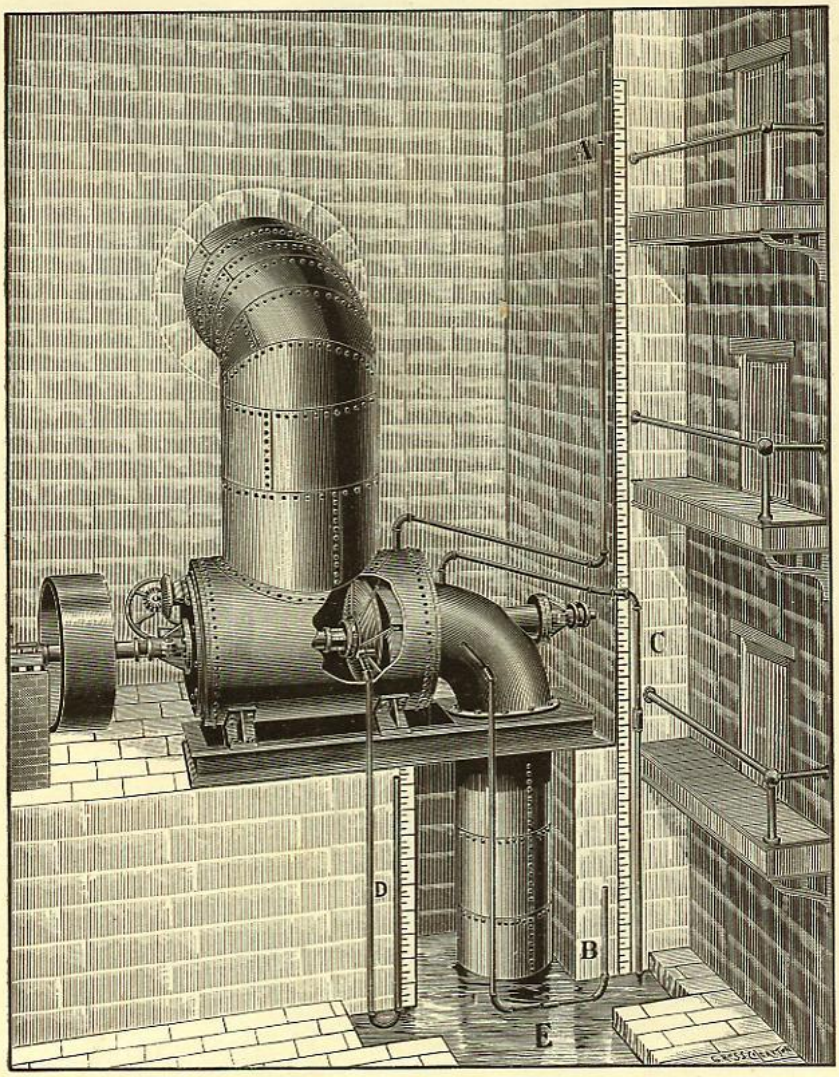


FIG. 44.

Fig. 44 illustrates our method of attaching Test-gauges to water-wheels. For description see pages 77 and 78.

Illustrating Power-Connections

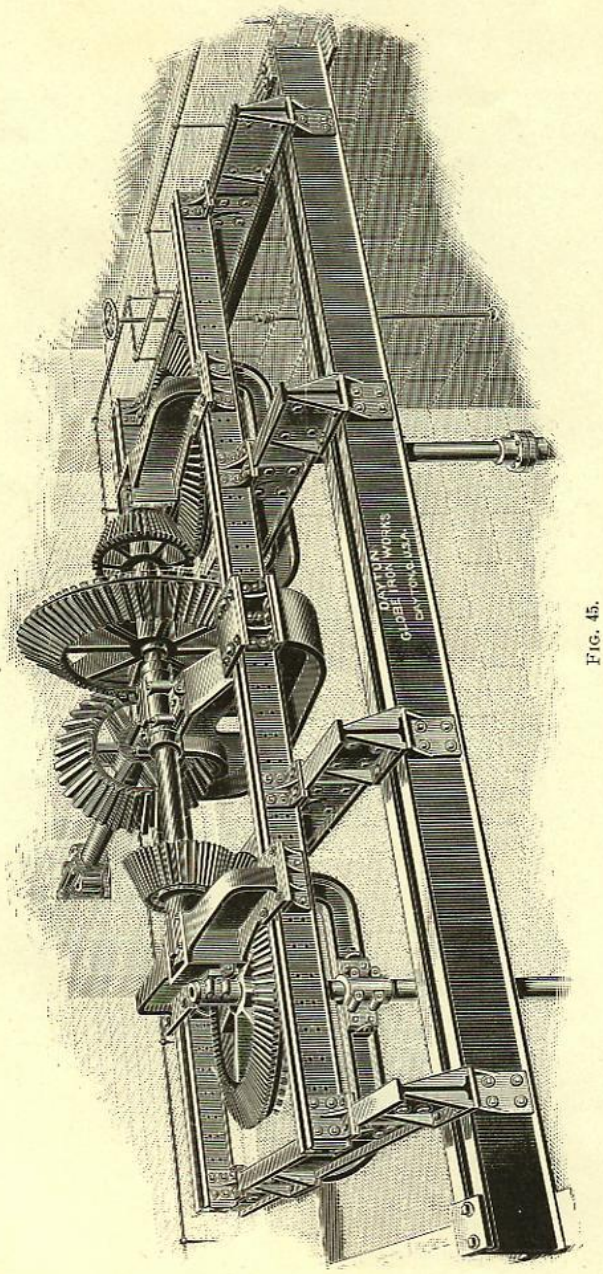


FIG. 45.

Fig. 45 represents power-connections, iron harness, etc., for the driving-gears for a pair of vertical wheels transmitting the power to a line shaft, running on the same level as and at right angles to the jack shaft.

Cast-iron Bridgetree, with Adjustable Bearings Supporting Pair of Bevel Mortise Gears

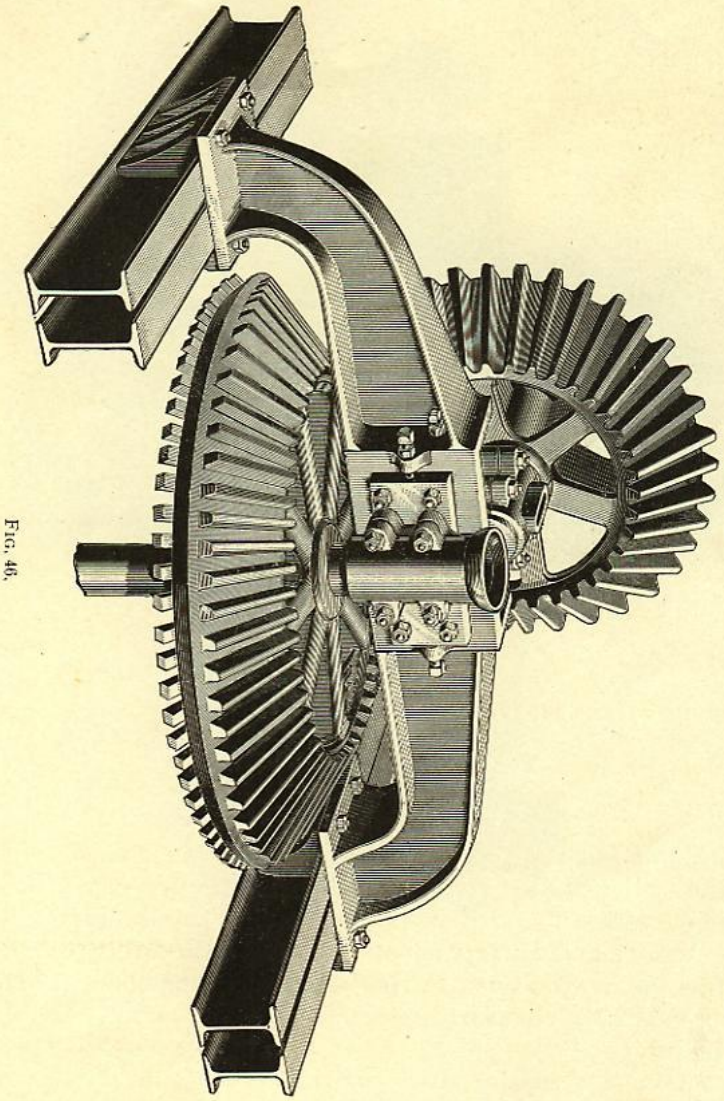


FIG. 46.

We have a full line of these bridgetrees of various sizes, prices of which will be quoted on application.

Power Transmission

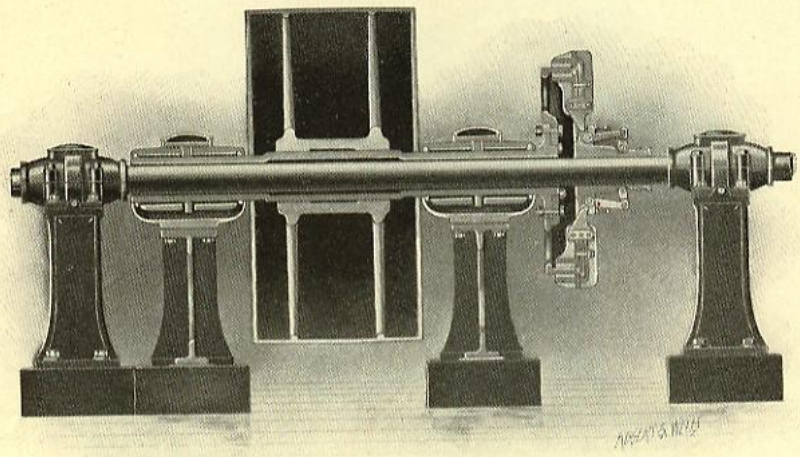


FIG. 47.

THE above cut illustrates our method of transmitting power by means of a hollow shaft or quill and friction-clutch coupling. The quill carries the driving-pulley, and is supported on its own bearings and stands independently of the main driving-shaft, which runs through it. This is a very desirable arrangement where it is desired to throw portions of the power on or off without stopping the entire power.

We make a specialty of power-transmitting machinery, such as gears, pulleys, sheaves, shafting, couplings, journal-boxes, etc., for all of which we have a complete line of patterns, enabling us to furnish work complete, without going outside of our own Works. Send for copy of Power-Transmission Catalogue.

Flume-Valves

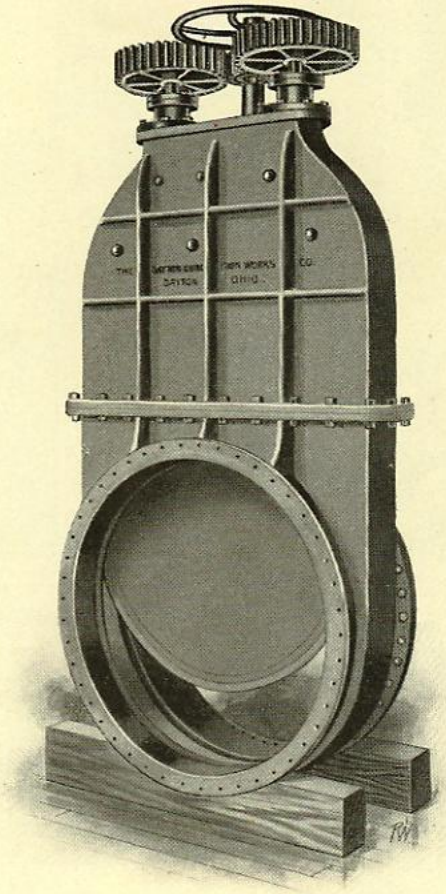


FIG. 48.

WE are prepared to furnish flume-valves of the above design, ranging in size from 12 to 60 inches in diameter, with either bevel or spur gears. State requirements, and prices will be quoted on application.

Head-Gate Irons

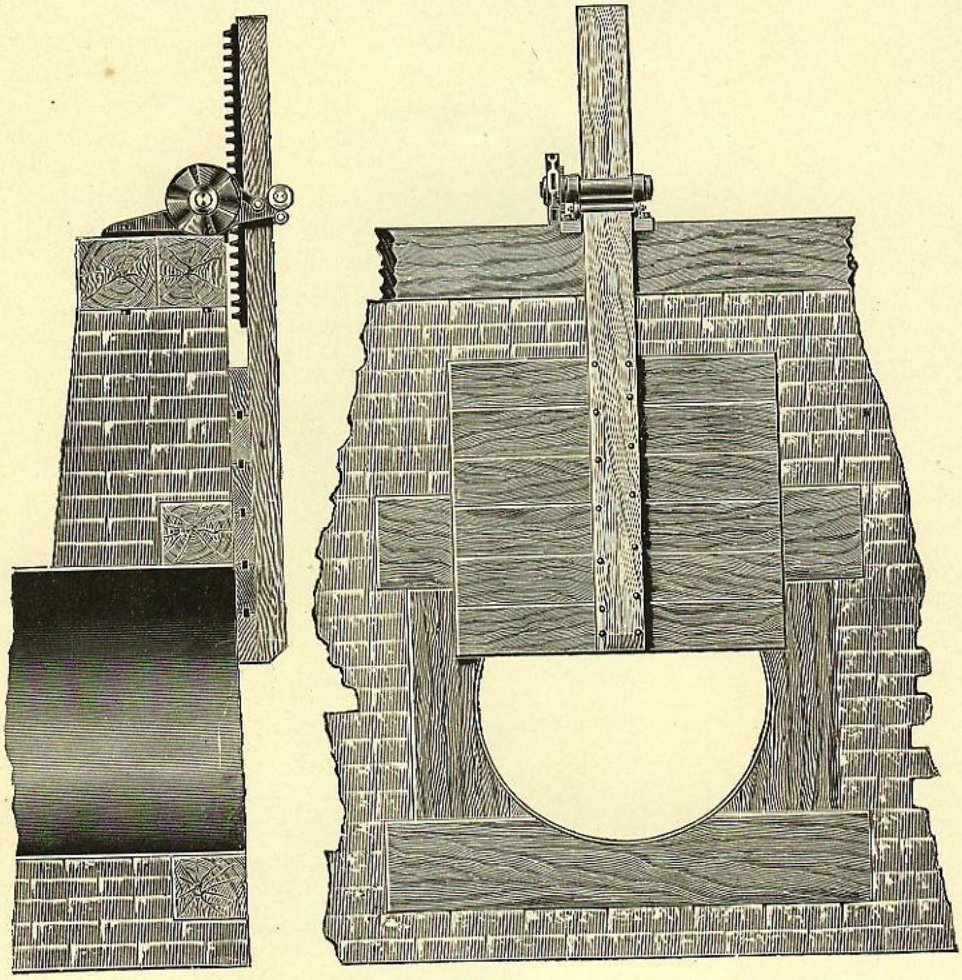


FIG. 49.

FIG. 49 represents a sectional and front elevation of Winch-wheel and Lever-hoist, with gate on the face of a bulkhead. This is a simple and strong arrangement.

Price List

No. 1 Hoist (Pinion 12 teeth, 3½-inch face, 1½-inch pitch)	$24 00
No. 2 Hoist (Pinion 14 teeth, 4½-inch face, 1¾-inch pitch)	36 00
No. 3 Hoist (Pinion 14 teeth, 4½-inch face, 2 -inch pitch)	42 00
No. 4 Hoist (Extra heavy. Each section of rack 3 feet 2 inches long) . .	48 00

Head-Gate Irons

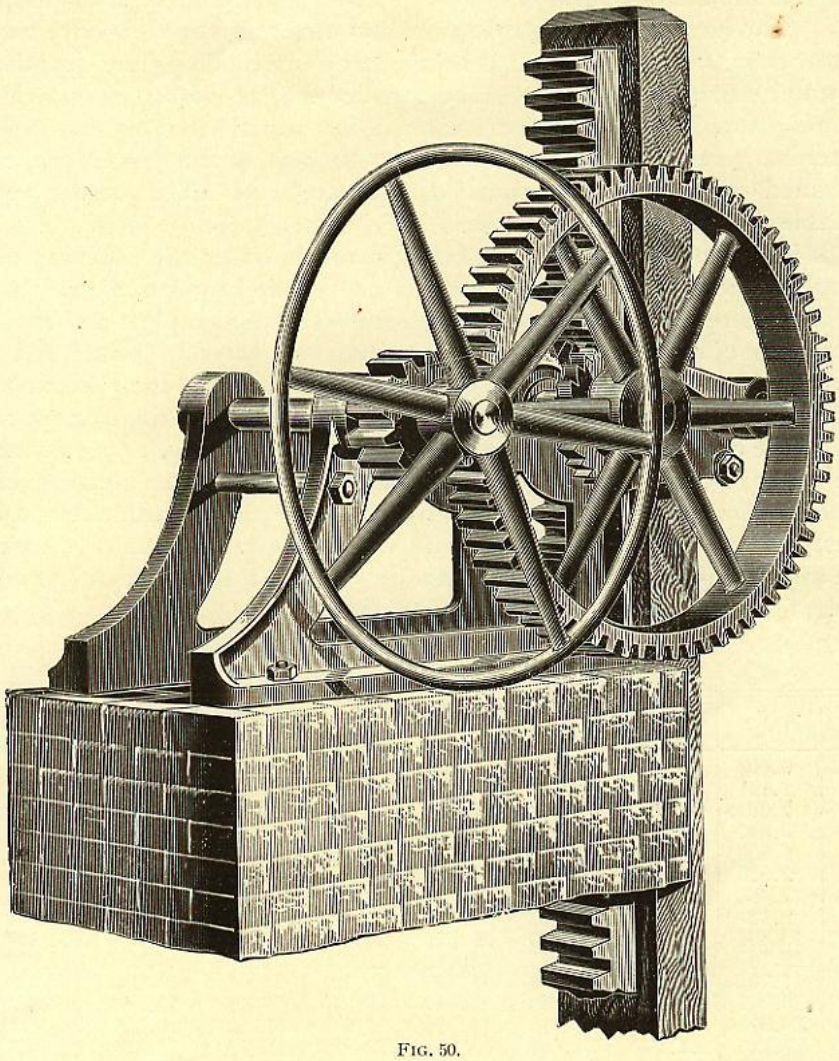


FIG. 50.

FIG. 50 represents a gate-stem operated by means of a hand-wheel on the pinion-shaft of the gear-hoist. This gate-hoist is geared back, and is of extra strength, being especially adapted for high heads. Prices quoted on application.

Measurement of Water Powers

THE subject of hydraulics is very little studied except by those who have made it a profession, consequently very few have any definite knowledge as to the manner of ascertaining the quantity of water passing in a stream. The force or motive power of water is its weight multiplied by the distance it has to fall, consequently, in order to give an intelligent answer as to how much power can be obtained from a stream, some data must be obtained before any reliable calculation can be made.

It is first necessary to find out how much water the stream will supply; secondly, how much head can be obtained by damming.

If the stream to be improved is a small one, the simplest and most accurate method of measuring the amount of water it passes is by means of a weir. A weir is a dam extending across the stream at right angles to the flow of the current, and having a rectangular notch cut in the crest or top plank of sufficient length and depth to pass all the water in the stream after it has first been set back to a dead level.

By taking the length of the weir and the vertical depth from the crest to the horizontal surface of still water up stream from the weir, the amount of water discharged can be obtained from the following table, figured from the formula of J. B. Francis:

Table of Weirs

In.	0	1/8	1/4	3/8	1/2	5/8	3/4	7/8
1	0.403	0.408	0.563	0.649	0.740	0.835	0.966	1.035
2	1.141	1.248	1.360	1.475	1.593	1.714	1.838	1.964
3	2.094	2.121	2.361	2.599	2.639	2.782	2.927	3.062
4	3.225	3.337	3.531	3.688	3.848	4.009	4.173	4.339
5	4.506	4.676	4 849	5.023	5.200	5.387	5.558	5.740
6	5.925	6.105	6.298	6.488	6.681	6.874	7.071	7.266
7	7.465	7.666	7.869	8.073	8.280	8.487	8.697	8.908
8	9.121	9.335	9.552	9.770	9.990	10.211	10.427	10.657
9	10.884	11.111	11.340	11.571	11.804	12.037	12.272	12.509
10	12.747	13.147	13.228	13.471	13.716	13.961	14.208	14.457
11	14.707	14.957	15.211	15.465	15.721	15.978	16 236	16.495
12	16.757	16.206	17.283	17.549	17.816	18.083	18.352	18.622
13	18.895	19.167	19.445	19.718	19.996	20.247	20.558	20.834
14	21.116	21.400	21.684	21.970	22.258	22.546	22.835	23.127
15	23.418	23.708	24.007	24.302	24.600	24.897	25.195	25.496
16	25.800	26.102	26.406	26.712	27.019	27.325	27.634	27.943
17	28.256	28.566	28.881	29.195	29.512	29.829	30 145	30.464
18	30.785	31.106	31.429	31.752	32.075	32.403	32.733	33.055

The table of weirs gives the number of cubic feet of water per minute that will pass over a weir for each inch in width, and from 1 to 18⅞ inches in depth. In the left-hand column of figures is the depth

of weir, and in the second column, under 0, is the number of cubic feet for the even inches in depth. In the third column, under ⅛, is the amount of the second column, with the additional amount due the additional ⅛ inch in depth added. The fourth column, under ¼, is for ¼ added, and so on across the table, from left to right.

Suppose we have a weir 10 inches in depth; run down the left-hand column to the figure 10, opposite and in the next column to the right will be found 12.747, the number of cubic feet discharged per minute, 1 inch in width and 10 inches in depth. The next column, under ⅛, is the amount for 10⅛ in depth, and so on.

By multiplying the number of cubic feet that one inch in width will discharge by the width of weir in inches, it will give the total discharge of weir per minute

Where measurement by weir is impracticable, and the stream very large, the amount of water can be gauged by ascertaining the average velocity of the current and area of cross section of the stream.

Select some place in the stream where there is a moderate current, or smooth, even flow of water, and measure the depth and width of the stream, and also the velocity of water by a float. The float should be made to sink well into the water, according to depth of stream.

If the stream be of considerable width, and the flow of water not uniform the entire width, the velocity should be taken near the shore, and also in the center; and the average velocity per minute in feet taken, and if the bed of the stream be uneven, the depth should be taken at a number of points in the width, and the average taken.

To ascertain the cubic feet, multiply the depth by the width; this product by the velocity in feet per minute, which will give the number of cubic feet per minute. To ascertain the horse-power, multiply the number of cubic feet thus obtained by 62.33, this product by the number of feet head that can be made available, and divide by 33.000, which will give the number of horse-power at the full value of the water. The number of effective horse-power which can be utilized will depend on the percentage of efficiency which the wheel will give.

By sending us the velocity, width and depth, and the entire fall or head that can be obtained, we can return the number of horse-power that the stream will produce.

If the power is improved, measure the apertures through which the water is drawn; and the distance from the surface to the center of aperture, and give, at the same time, the form of aperture.

The amount of water that will discharge through an aperture (theoretically) is obtained by multiplying its area by the velocity due the head measured from the surface to the center of the orifice. A

table of the theoretical velocity of water under various heads is given on pages 110 to 114. The actual discharge depends, however, on the form of the aperture, and this should in all cases be given, so that the proper coefficient can be taken for ascertaining the actual discharge.

By thus determining number of cubic feet per minute and comparing with the number of cubic feet discharged by our Turbines, it will determine what size wheel will be adapted to the amount of water.

Construction of Head-Races, Wheel-Pits and Tail-Races

UNDER the above heading we propose to make some practical remarks for the benefit of any who will avail themselves of our experience and observation. The importance of large and sufficient canals in the improvement of water-powers is appreciated by but comparatively few who are using water as a motive power, consequently in very many instances the subject receives but little consideration. It is very often the case that much valuable power is lost in consequence of insufficient head-races, flumes, wheel-pits and tail-races. The first thing that should be considered, where a water-power is to be improved, is, how many horse-power will be required or can be obtained, and how many cubic feet of water per minute will be required to produce the requisite number of horse-power with the fall to be employed. When this is determined, the canals and wheel-pits should be constructed of sufficient size to allow the water to pass to and from the water-wheels at a velocity not to exceed two feet per second, and no tail-race should have less than two feet of dead water before the wheels are put in motion. Where a very large amount of water is to be employed it would be better to have at least three to six feet of dead water the entire length of tail-race. By having this depth of water in the tail-race, as soon as the water is discharged from the wheels it displaces the dead water, and consequently there is but little, if any, loss of head. In order to make our point plain, we will suppose the bottom of the tail-race is sunk only to the level of the water in the river or receiving canal; the consequence would be the water discharged from the wheels would rise in the tail-race in proportion to its width and quantity of water used, while if there was the desired depth, as before stated, the water discharged from wheels would displace the dead water, and at once

conform to the general level of water in the tail-race and river. We very frequently see two or three feet head lost in water powers from the want of proper consideration.

Suppose we have a fall of twenty feet, and wish to employ 402 horse-power, which we find by the tables will require one 51-inch **New American Wheel,** using 13353 cubic feet of water per minute. For this amount of water flowing at the velocity named the cross-section of canals would be 111.27 square feet; thus — 13353÷(2x60)=111.27. The cross-sections of all passages to and from the pen-stock or flume in which the wheel is placed should equal 111.27 square feet. This, of course, includes the opening under the pen-stock for the water to escape after it leaves the wheel. This cross-section of both head and tail-race should be below the low water line of river.

Practice demonstrates that it is advisable to have as much room to pass the water from the wheels as there is to get it to them. And there is no argument that disproves the correctness of this theory, as the same water passed through the wheels has to be passed off below them—although this cannot in all cases be done without more expense than most persons are willing to incur. But as this is a subject of great importance, we here give a definite rule which will serve as a guide in determining what the capacity of canals should be in order to secure the best results from the use of water for any number of horse-power under a given head. By referring to the tables it will be seen what size wheel or wheels will be required to produce the requisite horse-power under the head to be employed, and the number of cubic feet of water discharged per minute, from which calculations can be made what the cross-section of canals would be in square feet.

For any diameter of wheel or wheels, under any head, there should be one square foot of cross-section in flume and tail-race for every one hundred and twenty cubic feet of water used per minute.

We have given this proportion, which is large enough to secure the best result from the use of water applied to a turbine.

The construction of large flumes is of great advantage, as when the head is reduced from any cause, there may still be sufficient capacity to supply the demand. Great advantage will also be found in long-continued cold seasons, when ice is formed so as to seriously obstruct the flow of water.

It is desirable to bring the water as near a state of rest as possible before entering the wheels, and as near the same condition after passing the wheels. There are many who are using water as a motive power, and setting turbine wheels, who have had a very limited experience, and are not aware of the importance of proper application,

and believe that comparatively small water-ways will answer fully as well as that which is absolutely necessary in order to utilize a good percentage of the full power of the water employed. Our object is to utilize all the power we can, rather than to sacrifice power in order to save a small outlay in the construction of sufficient inlets and outlets for water.

It is very seldom that wheel-pits and tail-races are made with the comparative capacity we have named. One-half the cross-section as above given, in wheel pits and tail-races, is quite common, and from all appearances, turbines under such conditions may give satisfaction when the full power of the wheels is not required. But at the same time the same wheels would produce more power with the same amount of water, were all the conditions as favorable as they could be made in many locations, with a very small additional expense.

Directions for Setting Wheels

THEY are placed in flumes or penstocks, and are consequently entirely submerged, free from ice; and the water can be shut off at any time, and the wheels left dry for the removal of flood-wood or foreign substances. The first thing to be done in preparing to set wheels is to excavate wheel-pits, (if there be none or not of sufficient depth,) put down mudsills, and sheet them over with two-inch plank (unless there be rock bottom). These pits must be from two to six feet in depth, according to the size of the wheel. It should always be borne in mind that a too free discharge can not be made. On low heads, ten feet or less, the wheels should be set so that the lower end of cylinder will be in tail-water five or six inches when wheels are standing. The deck-sills, or timbers on which the deck or floor of penstocks is placed, and on which the wheel-case will set, should be framed into corner posts, and be two inches wider than the posts, so as to leave a projection of two inches on the inside of penstocks for the deck-plank or floor to rest on. There should be corner pieces spiked on the inside of deck-sills to assist in supporting the deck-plank. These form an octagon, and should be the same depth as sills, and three or four inches thick. Where penstocks are large, (which is very desirable,) there should be intermediate sills framed into main sills, leaving a square of sufficient size to cut the whole through the deck-plank for wheels. The diameter of these holes for the different size New American wheels will be found in the table of dimensions of the New American Turbine, pages 12 and 15.

When the penstocks are completed there should be not less than from two to six feet of clear discharge from the lower side of these sills down to the sheeting in the bottom of wheel pits, and the same depth should be continued the entire length of tail-race, otherwise there will be a loss of head.

On high heads (twelve feet and upward) wheels may be set above tail-water, with draft-tubes below wheels, extending into tail-water. Where this is done there should be the same depth of tail-water as if the wheels were set at the bottom of fall. In constructing wood flumes for the purpose of setting wheels in this manner, the corner posts only need extend down.

The sills for deck plank or floor of flumes, on which the wheels rest, will be framed into corner post at any desired distance from tail-water, and the intermediate post framed into sills and caps in the usual manner. If the draft tubes are made of wood staves, the planks of which they are made must be sound, free from any imperfections, well seasoned, and not less than two and one-half inches thick. The utmost care should be taken in their construction, as they must be perfectly air-tight. Iron draft-tubes are preferable to wood, as there is greater certainty of getting them perfect, and their cost does not greatly exceed that of wooden tubes. If wooden tubes are used, the upper end will be spiked into a circle cut into deck plank, and be banded below deck with the bands sufficiently close to make the tubes air-tight. The lower end must extend into tail-water not less than six inches when the water is shut off, and have the required depth of water from the lower end of tubes to bottom of wheel-pit, (as above named,) that there may be a free escape, and reaction from the bottom prevented.

The corner post of penstock must be rabbeted two inches one way and four the other, to receive the side-plank. This makes the strongest job, and prevents leakage. This will require corner posts twelve by fourteen inches, when the intermediate posts are ten inches.

When two or more wheels are to be used in the same mill, the penstock or flume can be made to receive all the wheels. This will require intermediate sills to support the deck-plank.

We are aware that mill-wrights generally understand the nature of all we have here and elsewhere said in regard to the construction of flumes and setting our wheels, but for the information of the inexperienced, and for the benefit of the owners of water powers, we have no doubt some general principles will be of great advantage. If these general principles are adhered to, they will prevent failures in the construction of flumes and wheel-pits, and in setting our Turbine Wheels.

We are induced to dwell on this subject in consequence of its great importance, and also from the fact that many who are engaged in the construction of mills and improvements of water powers, have had but little opportunity of giving the subject that consideration which its importance demands. If such persons will follow these general proportions and arrangements in their operations, and have ordinary mechanical skill and judgment, serious mistakes will be avoided. Our article on construction of Head-Races, Flumes, Wheel-Pits and Tail-Races, page 88, deserves full consideration, and will be found of great advantage to those who are at a loss to determine the proportions flumes and canals should have to the amount of water to be employed.

We are also aware, from our experience, that these directions and proportions can not always be strictly carried out in all locations, or in old mills, which have been built without reference to putting in Turbine Wheels. In such instances judgment must be exercised, and the best possible arrangements made under the circumstances. Care must be taken not to deviate so far as to destroy the effective force of the water by an insufficient supply into the flumes, or contracted discharge from the wheels. The supply of water into the penstocks should be large, so that it will stand as quietly over the wheels as possible, as the effective force of water is diminished by flowing rapidly into penstocks. All that is essential to make them do good service is to have a place to hold the water, have a good supply of water into the penstocks, a free discharge below, and have the wheels set level on solid foundations.

The floor or deck of the penstock can be made of rough plank, spiked down; and, after cutting the hole to receive the wheel-case, spike a cant made of plank two or three inches thick on the face of the deck, of sufficient width to receive the flange of the case. After spiking this cant down, plane it level on the face, which will make the wheel level and the shaft plumb, as the bottom of the cases are turned true, and are at right angles to their shafts. When two or more wheels are sent to one place, each set will be numbered to distinguish them.

In some instances where a square penstock cannot be made of sufficient size, the space may be such that a circular flume can be built of staves, which answers quite as well. Where such is the case, place the deck plank on timbers or masonry, and cut a groove in the face to insert the staves; band them with iron, place two timbers across the top, and put bolts through each end of these timbers, extending through the lower deck, and clamp the tub down. If the water is to be admitted through an ordinary open fore-bay, frame two posts at the tub formed by the staves, equal distance apart as the width of

fore-bay, pass the bands around the tub, and the ends through these posts with screws and nuts, and clamp firmly; or, the water can be admitted by a round cylinder. On the two timbers, already described, on top of the round penstock, other timbers can be securely placed, if desired, to carry the gearing. This makes a good penstock, and will cost less than if made square for single wheels, as but a small amount of timber is required.

Very Large Wheels under Quite Low Heads

Where very low heads are to be utilized for power, say from three to five feet, and large turbines are to be used, there is but one way to make such powers a success; that is, to excavate deep wheel-pits and tail-races, and place the floor of flume at least two feet below the standing tail-water, and the bottom of fore-bays equally low in order to get a sufficient depth over the wheels, and also sufficient cross-section in the flumes leading to the wheels. It would be a much better plan to use two smaller wheels to obtain the power of one of the largest, as there would be less water concentrated at one point, and the flumes, wheel-pits and race-ways both to and from the wheels would be proportionately much wider. There is no serious objection to submerging our large turbines in tail-water, as they will not clog; the steps will not wear down under such low heads, and there will not be any repairs required below the dead water line for a great many years.

Setting Wheels above Tail-Water

WHEELS under high heads, in order to better adapt them to certain locations and conditions, are frequently placed some distance above tail-water, by using air-tight draft-tubes for conducting the water from the wheel. When this is done, there should be the same depth of wheel-pit and tail-water as would be the case were the wheel set at the bottom of the fall, and the end of the draft-tube should be submerged in the tail-water not less than six inches, when the wheel is not in motion.

Draft-tubes are made sufficiently large in diameter to receive the wheel-cylinder; and the upper ring or flange should be faced off true, so as to form a perfect joint with the flange of the wheel-case.

We very frequently rivet a boiler-iron draft-tube or extension to the cylinder of a vertical water wheel. We would not recommend using a draft-tube of much over twenty feet in length, on account of the difficulty of maintaining a perfect vacuum. The least air getting through the joints of the tube renders the vacuum imperfect, and there will be a consequent loss of head and burning out of the wheel step.

Beating and Washing Engines for Paper Mills

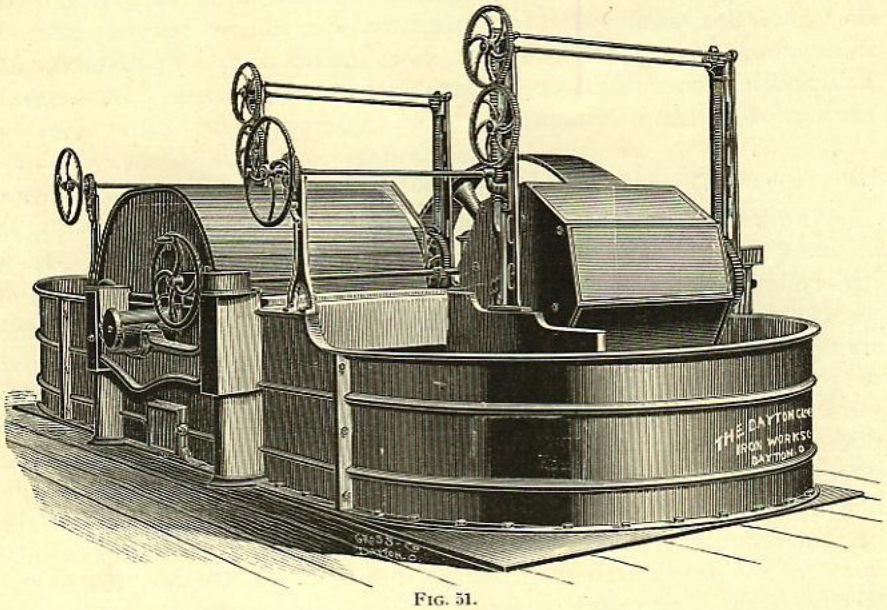


FIG. 51.

AN experience of over thirty years in the building of Washing and Beating engines for paper mills has enabled us to bring our engines to such a high degree of excellence, that the satisfaction and esteem in which they are viewed by all paper-mill owners who have them in use, make us feel justified in claiming, on account of the workmanship, turning qualities, substantial construction, and many other important features, that our engines are superior to all others manufactured.

We have a full line of patterns for cast-iron-tub engines of sizes ranging in capacity from 300 to 1,500 lbs., and have furnished engines for the manufacture of all kinds of paper.

The rolls range in size from one twenty-four inches in diameter, with 28-inch face, to one fifty-four inches in diameter, with 60-inch face. Our long experience in engine building has enabled us to determine the best proportions and construction for the proper beating or washing of stock.

The rolls of our engines are lightered at both the front and back by means of worm-wheels and lighter-screws, which raise the bars supporting the spindle. A collar is cast on the spindle just outside of the tub to prevent leakage.

The wooden fall-blocks are plated in the circle under the rolls with cast-iron plates one-half inch thick. The bed-plate boxes are made tapering, so as to fit the fall-block, and do not require keys to hold them in place.

Two washers are required on engines that work stock containing a large quantity of lime, which fills up the meshes of the wire-cloth; but for manilas, news, writing and book papers, one washer is sufficient. The cone cylinder washers are made with cast-iron heads, so arranged that they can be taken apart and cleaned, should the interior become foul.

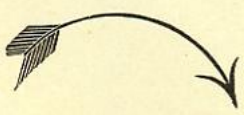
The hanging spout of the washer, which discharges into a cast-iron box bolted to the side of the engine tub, is quarter turn in form and is secured to the sliding frame, in which the cylinder is journaled, so that the weight of the hanging spout does not rest on the mouthpiece of the cylinder head, but is held in position by the arch. The upper surface of the washer box is planed so as to receive the washer stand and boxes, which carry the driving shaft of the washer.

We manufacture engines of three descriptions: namely, those constructed entirely of iron, except the inside of washers and the wood filling in rolls; those having the bottoms, fall blocks and midfeathers of wood, with iron tubs; and those constructed of wood, except the spindles, washer-heads, stands, fall block linings, bed plate boxes, and an iron coping about the top of the tubs.

All contracts for Beating or Washing Engines are made on printed specifications describing the dimensions and construction of each part of the engine.

Parties writing us for information in regard to our engine will please be particular to state:

1. The kind of stock to be worked and paper to be made.
2. Whether the engines are to be used as Beaters or as Washers. If the stock is to be washed and finished before turning out, as is the case with wrapping or strawboard, please so state.
3. The capacity desired.
4. Whether the stock in the engines is to turn to the right, *i. e.*, with the sun, or left hand, *i. e.*, against the sun.
5. If more than one engine is wanted, whether they are to work singly or in pairs.
6. Whether iron or wood tub engines are desired.
7. The number of washers desired on each engine and the number of wire cloth with which they are to be covered.



RIGHT HAND

LEFT HAND

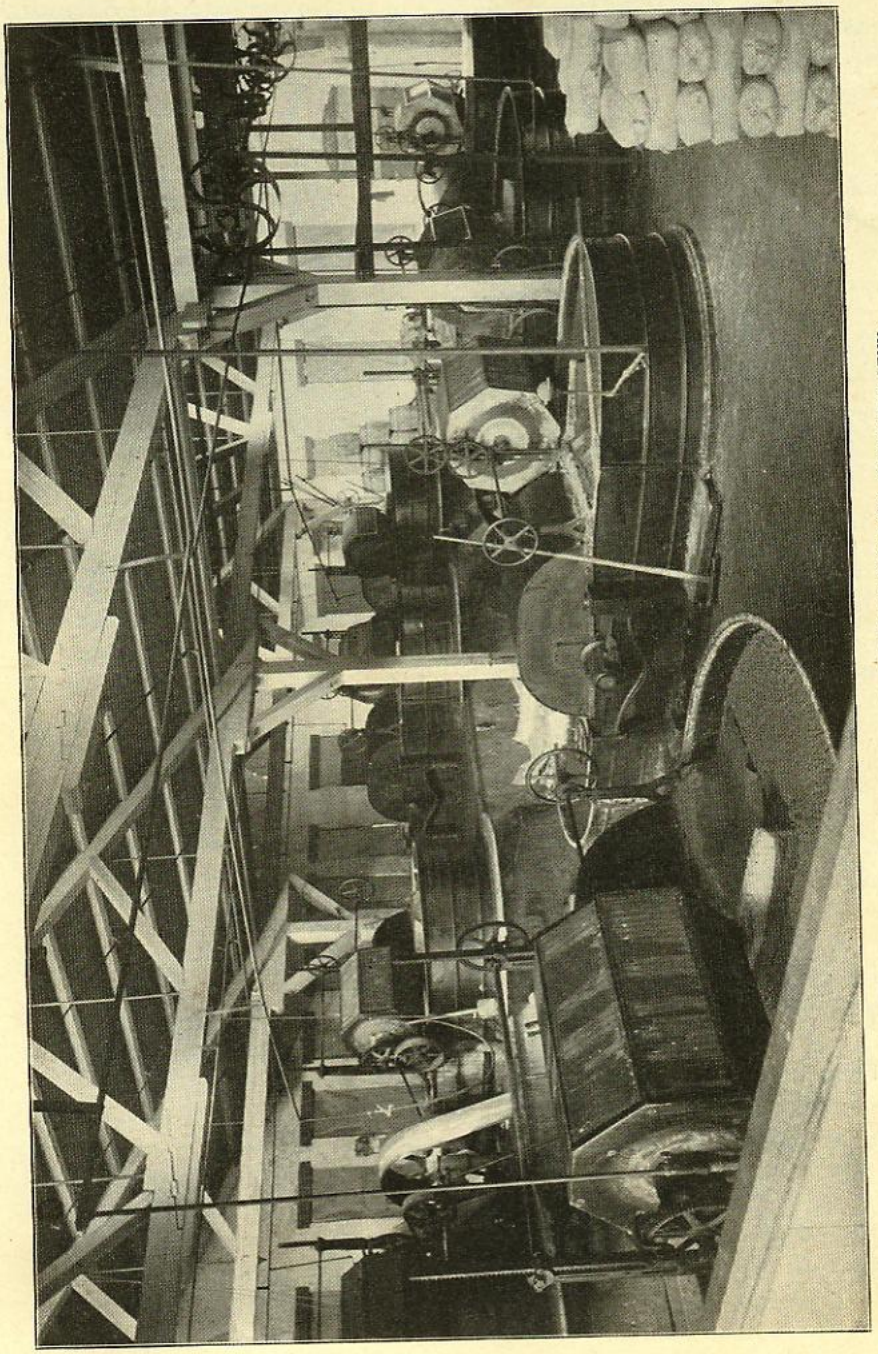


FIG. 52. INTERIOR OF BEATER-ROOM OF TARENTUM PAPER CO., TARENTUM, PENN.

Rag-Engine Rolls

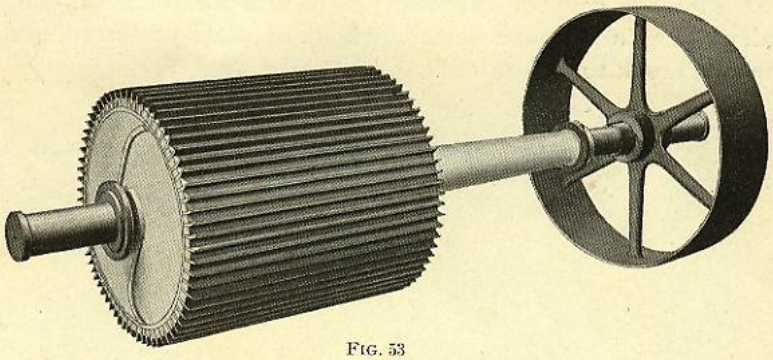


FIG. 53

Hydrants

With four, five and six-inch discharge pipe.

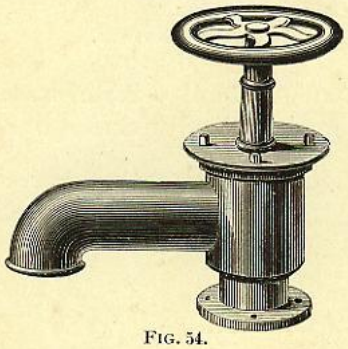


FIG. 54.

Rag-Engine Fly-Bars

Which we can furnish of any thickness desired.

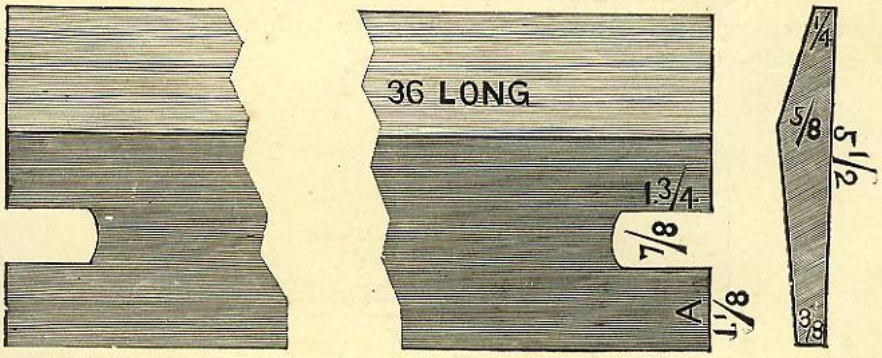


FIG. 55.

Bed-Plates for Rag-Engines

The following cuts show three styles of bed-plates for Rag-Engines. In ordering engines please name the style of plate preferred, and also the kind of stock to be worked.

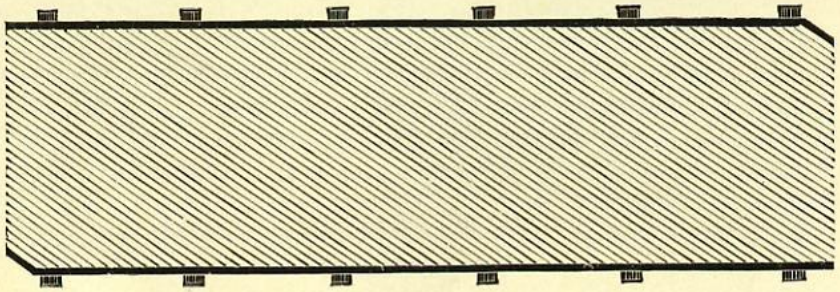


FIG. 56.
ANGLE BED-PLATE.

Fig. 56 represents an Angle Bed-Plate made of sheet steel, with wood filling. Can be made of any thickness of steel desired.

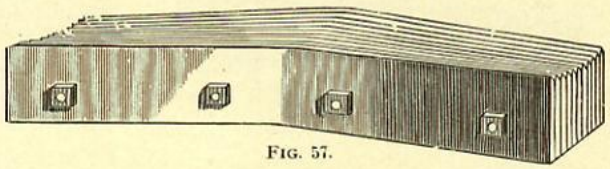


FIG. 57.

Twelve bar steel laid elbow bed-plate (Fig. 57), made of iron laid with steel, and with any number of bars desired. We also furnish plates, elbow in form, made of steel plates with wood filling, suitable for beating-engines.

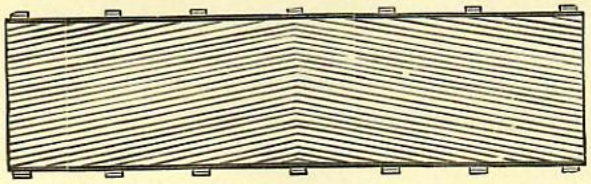


FIG. 58.
COMBINATION BED-PLATE, STEEL PLATES, WOOD FILLING.

Mixing and Settling Tanks

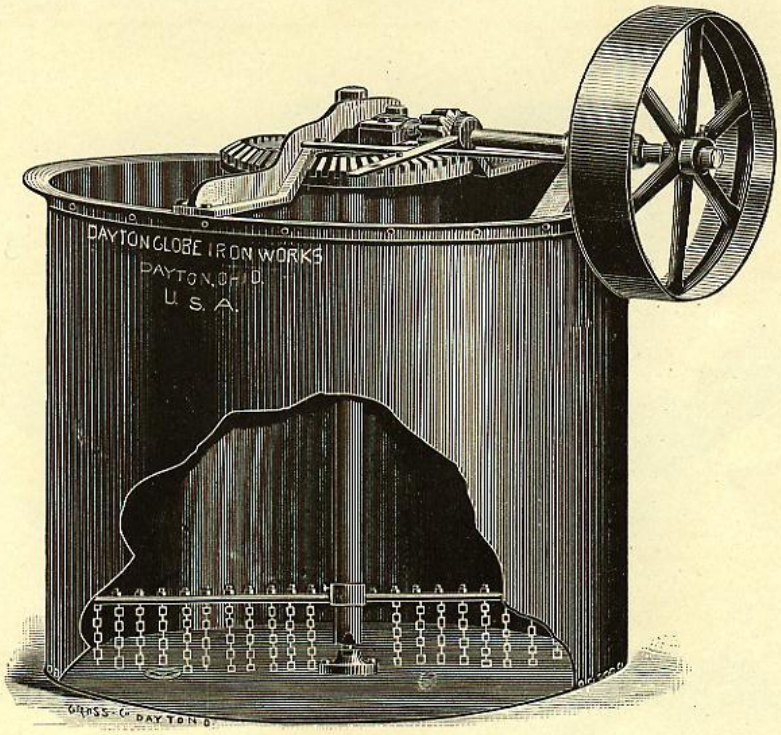


FIG. 59.

WE are prepared to furnish wrought-iron Mixing and Settling Tanks for paper mills, of any diameter and depth desired; and also manufacture cast-iron tanks of the following sizes:

7 feet in diameter, 6 or 9 feet deep.
8 feet 6 inches in diameter, 6 to 12 feet deep.
9 feet 6 inches in diameter, 6 to 12 feet deep.

They are supplied with agitators, driving-gears, cocks and syphons. Prices quoted on application.

The Dayton Wood-Pulp Grinder

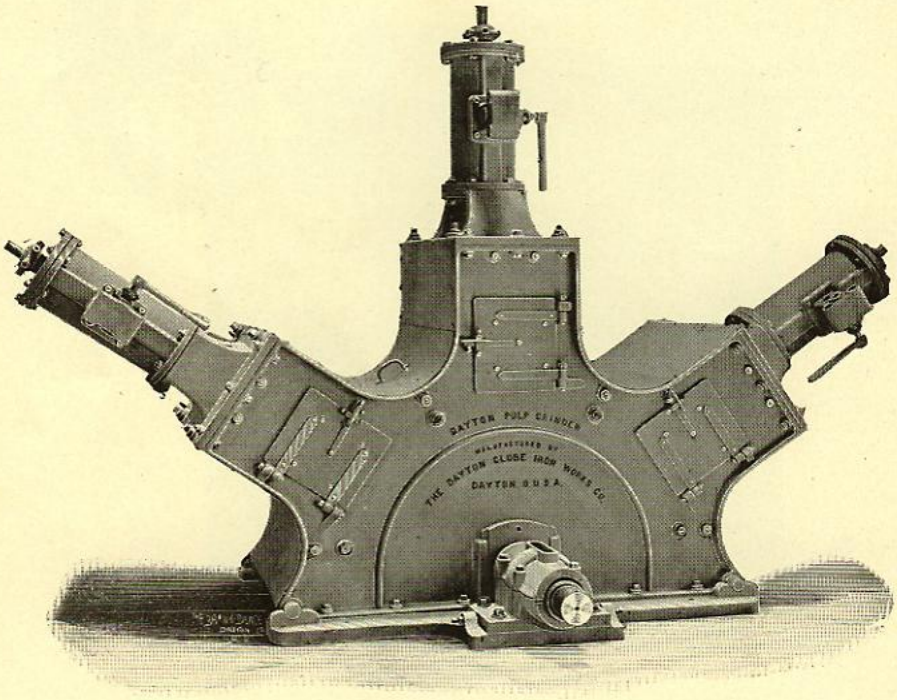


FIG. 60.

For full description of the Dayton Wood-pulp Grinder, send for special catalogue.

The Dayton Gas and Gasoline Engine

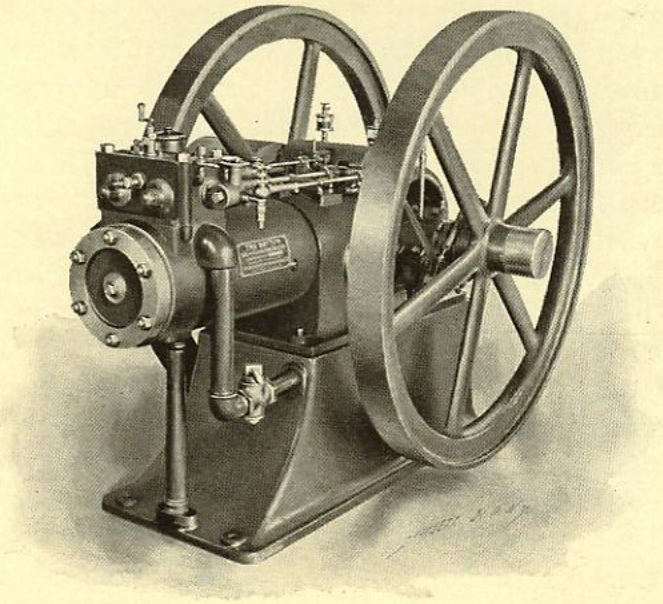


FIG. 61.

THE Dayton Gas and Gasoline Engine can be operated with gasoline from supply tank lower than engine, distillate, coal gas, producer gas, or natural gas. It is built in sizes from 3 horse-power to 50 horse-power. The Dayton occupies the same high and inaccessible position among gas engines as the New American does among turbines. Send for special catalogue for full particulars.

Areas and Circumferences of Circles

Diameter in inches	Circumference in feet	Area in square inches
1	.2617	.7854
2	.5236	3.1416
3	.7853	7.0686
4	1.0472	12.5664
5	1.309	19.6350
6	1.5707	28.2744
7	1.8326	38.4846
8	2.0943	50.2656
9	2.3562	63.6174
10	2.6179	78.5400
11	2.8797	95.0334

Diameter in ft.	Diameter in in.	Circumference in feet	Area in square feet
1	0	3.1416	.7854
	1	3.4034	.9217
	2	3.6652	1.0690
	3	3.927	1.2271
	4	4.1888	1.3962
	5	4.4506	1.5761
	6	4.7124	1.7671
	7	4.9742	1.9689
	8	5.236	2.1816
	9	5.4978	2.4052
	10	5.7596	2.6398
	11	6.0214	2.8852
2	0	6.2832	3.1416
	1	6.545	3.4087
	2	6.8068	3.6869
	3	7.0686	3.9760
	4	7.3304	4.2760
	5	7.5922	4.5869
	6	7.854	4.9087
	7	8.1158	5.2413
	8	8.3776	5.5850
	9	8.6394	5.9395
	10	8.9012	6.3049
	11	9.163	6.6813
3	0	9.4248	7.0686
	1	9.6866	7.4666
	2	9.9484	7.8757
	3	10.2102	8.2957
	4	10.472	8.7265
	5	10.7338	9.1683
	6	10.9956	9.6214
	7	11.2574	10.0847
	8	11.5192	10.5591
	9	11.781	11.0446
	10	12.0428	11.5409
	11	12.3046	12.0481
4	0	12.5664	12.5664
	1	12.8282	13.0952
	2	13 09	13.6353
	3	13.3518	14.1862
	4	13.6136	14.7479
	5	13.8734	15.3206
	6	14.1372	15.9043
	7	14.499	16.4986
	8	14.6608	17.1041
	9	14.9226	17.7205
	10	15.1844	18.3476
	11	15.4462	18.9858
5	0	15.708	19.6350
	1	15.9698	20.2947
	2	16.2316	20.9656
	3	16.4934	21.6475
	4	16.7552	22.3374
	5	17.017	23.0437
	6	17.2788	23.7583
	7	17.5406	24.4835
	8	17.8024	25.2199
	9	18.0642	25.9672
	10	18.326	26.7251
	11	18.5878	27.4943
6	0	18.8496	28.2744
	1	19.1114	29.0649
	2	19.3732	29.8668
	3	19.635	30.6796
	4	19.8968	31.5029
	5	20.1586	32.3376
	6	20.4204	33.1831
	7	20.6822	34.0391
	8	20.944	34.9065
	9	21.2058	35.7847
	10	21.4676	36.6735
	11	21.7294	37.5736
7	0	21.9912	38.4846
	1	22.2530	39.4060
	2	22.5148	40.3388
	3	22.7766	41.2825
	4	23 0384	42.2367
	5	23.3002	43.2022
	6	23.5620	44.1787
	7	23.8238	45.1656
	8	24.0856	46.1638
	9	24.3474	47.1730
	10	24.6092	48.1926
	11	24.8710	49.2236
8	0	25.1328	50.2656
	1	25.3946	51.3178

Areas and Circumferences of Circles

Diameter ft.	Diameter in.	Circumference in feet	Area in square feet	Diameter ft.	Diameter in.	Circumference in feet	Area in square feet	Diameter ft.	Diameter in.	Circumference in feet	Area in square feet
8	2	25.6564	52.3816	10	11	34.2958	93.5986	13	8	42.9352	146.6949
	3	25.9182	53.4562	11	0	34.5576	95.0334		9	43.197	148.4896
	4	26.18	54.5412		1	34.8194	96.4783		10	43.4588	150.2943
	5	26.4418	55.6377		2	35.0812	97.9347		11	43.7206	152.1109
	6	26.7036	56.7451		3	35.343	99.4021	14	0	43.9824	153.9384
	7	26.9654	57.8628		4	35.6048	100.8797		1	44.2442	155.7758
	8	27.2272	58.9920		5	35.8666	102.3689		2	44.506	157.6250
	9	27.4890	60.1321		6	36.1284	103.8691		3	44.7678	159.4852
	10	27.7508	61.2826		7	36.3902	105.3794		4	45.0296	161.3553
	11	28.0126	62.4445		8	36.652	106.9013		5	45.2914	163.2373
9	0	28.2744	63.6174		9	36.9138	108.4342		6	45.5532	165.1303
	1	28.5362	64.8006		10	37.1756	109.9772		7	45.815	167.0331
	2	28.798	65.9951		11	37.4374	111.5319		8	46.0768	168.9479
	3	29.0598	67.2007	12	0	37.6992	113.0976		9	46.3386	170.8735
	4	29.3216	68.4166		1	37.961	114.6732		10	46.6004	172.8091
	5	29.5834	69.6440		2	38.2228	116.2607		11	46.8622	174.7565
	6	29.8452	70.8823		3	38.4846	117.8590	15	0	47.124	176.7150
	7	30.107	72.1309		4	38.7464	119 4674		1	47.3858	178.6832
	8	30.3688	73 3910		5	39.0082	121.0876		2	47.6476	180 6634
	9	30.6306	74.6620		6	39.27	122.7187		3	47.9094	182.6545
	10	30.8924	75.9433		7	39.5318	124.3598		4	48.1712	184.6555
	11	31.1542	77.2362		8	39.7936	126.0127		5	48.433	186.6684
10	0	31.416	78 5400		9	40.0554	127.6765		6	48.6948	188.6923
	1	31.6778	79.8540		10	40.3172	129.3504		7	48 9566	190 7260
	2	31.9396	81.1795		11	40.579	131.0360		8	49.2184	192.7716
	3	32.2014	82.5160	13	0	40.8408	132.7326		9	49 4802	194.8282
	4	32.4632	83.8627		1	41.1026	134.4391		10	49.742	196.8946
	5	32.725	85.2261		2	41.3644	136.1574		11	50.0038	198.9730
	6	32.9868	86.5903		3	41.6262	137.8867	16	0	50.2656	201.0624
	7	33.2486	87.9697		4	41.888	139.6260		1	50.5274	203.1615
	8	33.5104	89.3608		5	42.1498	141.3771		2	50.7892	205.2726
	9	33.7722	90.7627		6	42.4116	143.1391		3	51.051	207.3946
	10	34.034	92.1749		7	42.6734	144 9111		4	51.3128	

Table of Inches and Sixteenths Reduced to Decimals of a Foot

Sixteenths	0	1	2	3	4	5	6	7	8	9	10	11
0/16	.000	.083	.167	.250	.333	.417	.500	.583	.667	.750	.833	.917
1/16	.005	.089	.172	.255	.339	.422	.505	.589	.672	.755	.839	.922
2/16	.010	.094	.177	.260	.344	.427	.510	.594	.677	.760	.844	.927
3/16	.016	.099	.182	.266	.349	.432	.516	.599	.682	.766	.849	.932
4/16	.021	.104	.187	.271	.354	.437	.521	.604	.687	.771	.854	.937
5/16	.026	.109	.193	.276	.359	.443	.526	.609	.693	.776	.859	.943
6/16	.031	.115	.198	.281	.365	.448	.531	.615	.698	.781	.865	.948
7/16	.036	.120	.203	.286	.370	.453	.536	.620	.703	.786	.870	.953
8/16	.042	.125	.208	.292	.375	.458	.542	.625	.708	.792	.875	.958
9/16	.047	.130	.214	.297	.380	.464	.547	.630	.714	.797	.880	.964
10/16	.052	.135	.219	.302	.385	.469	.552	.635	.719	.802	.885	.969
11/16	.057	.141	.224	.307	.391	.474	.557	.641	.724	.807	.891	.974
12/16	.062	.146	.229	.312	.396	.479	562	.646	.729	.812	.896	.979
13/16	.068	.151	.234	.318	.401	.484	.568	.651	.734	.818	.901	.984
14/16	.073	.156	.240	.323	.406	.490	.573	.656	.740	.823	.906	.990
15/16	.078	.161	.245	.328	.411	.495	.578	.661	.745	.828	.911	.995

Weight of Rolled Iron Per Foot

Inch	Round	Square	Inch	Round	Square
1/4	.165	.211	3 1/4	28.040	35.704
3/8	.373	.475	3 1/2	32.512	41.408
1/2	.663	.845	3 3/4	37.332	47.534
5/8	1.043	1.320	4	42.464	54.084
3/4	1.493	1.901	4 1/4	47.952	61.055
7/8	2.032	2.588	4 1/2	53.760	68.448
1	2.654	3.380	4 3/4	59.900	76.264
1 1/8	3.360	4.278	5	66.752	84.480
1 1/4	3.172	5.280	5 1/4	73.172	93.198
1 3/8	5.019	6.390	5 1/2	80.304	102.24
1 1/2	5.972	7.640	5 3/4	88.000	111.75
1 5/8	7.010	8.926	6	97.000	121.66
1 3/4	8.128	10.325	6 1/2	112.16	142.88
1 7/8	9.333	11.883	7	130.05	165.63
2	10.616	13.520	7 1/2	149.33	190.14
2 1/8	11.988	15.263	8	169.85	216.34
2 1/4	13.440	17.112	8 1/2	191.80	244.22
2 3/8	12.975	19.066	9	215.04	273.79
2 1/2	16.688	21.120	9 1/2	239.60	305.10
2 5/8	18.293	23.292	10	265.40	337.90
2 3/4	20.076	25.56	10 1/2	292.68	372.70
2 7/8	21.944	27.939	11	321.21	409.00
3	25.000	30.416	12	382.20	486.70

Weight of Flat Rolled Iron Per Foot

Breadth in inches	THICKNESS								
	1/8 in.	3/16 in.	1/4 in.	3/8 in.	1/2 in.	5/8 in.	3/4 in.	7/8 in.	1 in.
1/2	.211	.316	.422	.634					
3/4	.316	.474	.633	.950	1.265	1.584			
1	.422	.633	.845	1.267	1.690	2.112	2.534	2.956	
1 1/4	.528	.792	1.056	1.584	2.112	2.640	3.168	3.696	4.224
1 3/8	.580	.870	1.161	1.742	2.325	2.904	3.484	4.065	4.646
1 1/2	.633	.949	1.266	1.900	2.535	3.168	3.802	4.435	5.069
1 3/4	.739	1.109	1.479	2.218	2.957	3.696	4.435	5.178	5.914
2	.845	1.267	1.689	2.534	3.379	4.224	5.069	5.914	6.758
2 1/4	.950	1.425	1.900	2.851	3.802	4.752	5.703	6.653	7.604
2 1/2	1.056	1.584	2.112	3.168	4.224	5.280	6.336	7.392	8.448
2 3/4	1.162	1.741	2.320	3.485	4.647	5.808	6.970	8.132	9.294
3	1.267	1.901	2.535	3.802	5.069	6.337	7.604	8.871	10.14
3 1/4	1.373	2.059	2.746	4.119	5.492	6.865	8.237	9.610	10.98
3 1/2	1.479	2.218	2.957	4.436	5.914	7.393	8.871	10.35	11.83
3 3/4	1.584	2.376	3.168	4.752	6.336	7.921	9.505	11.09	12.67
4	1.690	2.535	3.380	5.069	6.756	8.445	10.14	11.83	13.52
4 1/2	1.901	2.851	3.802	5.703	7.604	9.507	11.406	13.31	15.31
5	2.112	3.168	4.224	6.336	8.449	10.569	12.672	14.78	16.90
6	2.535	3.801	5.069	7.594	10.138	12.679	15.207	17.74	20.28
7	2.957	4.434	5.914	8.870	11.827	14.789	17.742	20.69	23.65
8	3.379	5.067	6.759	10.137	13.517	16.899	20.28	23.64	27.03
9	3.801	5.700	7.602	11.404	15.204	19.005	22.80	26.59	30.40
10	4.223	6.333	8.446	12.671	16.892	21.115	25.34	29.54	33.78
11	4.645	6.967	9.294	13.938	18.588	23.225	27.88	32.49	37.17
12	5.067	7.600	10.134	15.205	20.268	25.335	30.40	35.44	40.40

Weight of a Square Foot of Cast and Wrought Iron, Copper and Brass

FROM ONE-SIXTEENTH TO ONE INCH IN THICKNESS

Thickness, inches	Cast Iron, pounds	Wrought Iron, pounds	Copper, pounds	Brass, pounds
1/16	2.346	2.517	2.89	2.675
1/8	4.693	5.035	5.781	5.35
3/16	7.039	7.552	8.672	8.025
1/4	9.386	10.07	11.562	10.7
5/16	11.733	12.588	14.453	13.375
3/8	14.079	15.106	17 344	16.05
7/16	16.426	17.623	20.234	18.725
1/2	18.733	20.141	23.125	21.4
9/16	21.119	22.659	26.016	24.075
5/8	23.466	25.176	28.906	26.75
11/16	25.812	27.694	31.797	29.425
3/4	28.159	30.211	34.688	32.1
13/16	30.505	32.729	37.578	34.775
7/8	32.852	35.247	40.469	37.45
15/16	35.199	37.764	43.359	40.125
1	37.545	40.282	46.25	42.8

Weight of Metals

Cubic inches X .252 . . . . . = pounds of Zinc
Cubic inches X .26 . . . . . = pounds of Cast Iron
Cubic inches X .262 . . . . . = pounds of Tin
Cubic inches X .28 . . . . . = pounds of Wrought Iron
Cubic inches X .283 . . . . . = pounds of Steel
Cubic inches X .3 . . . . . = pounds of Brass
Cubic inches X .32 . . . . . = pounds of Copper
Cubic inches X .41 . . . . . = pounds of Lead
Cubic inches X .281 . . . . . = pounds of Babbitt.

Metric System of Weights and Measures

The Metric System was authorized by Act of Congress July 28, 1886. The values of the base of each measure, viz.: Meter, Liter, Stere, Are and Gram are decreased or increased by the following prefixes: Milli, .001 or 1,000th part; Centi, .01 or 100th part; Deci, .1 or 10th part; Deka, 10 times value; Hekto, 100 times value; Kilo, 1,000 times value; Myria, 10,000 times value.

Measures of Length, Capacity and Weight

LENGTH	Kilo-meter	Hectometer	Dekameter	Meter	Decimeter	Centimeter	Millimeter
CAPA-CITY	Kiloliter or Stere	Hectoliter or Decistere	Decaliter or Centistere	Liter or Millistere	Deciliter	Centiliter	Milliliter
WEIGHT	Kilo-gram	Hecto-gram	Dekagram	Gram	Decigram	Centi-gram	Milligram
	1	10	100	1,000	10,000	100,000	1,000,000
		1	10	100	1,000	10,000	100,000
			1	10	100	1,000	10,000
				1	10	100	1,000
				.1	1	10	100
				.01	.1	1	10
				.001	.01	.1	1

1 myriameter equals 10 kilometers equals 10,000 meters.
1 tonne equals 1,000 kilograms equals 100 quintals equals 10 myriagrams.
1 gram equals 1 cubic centimeter of distilled water at its maximum density at sea level in latitude of Paris and barometer at 760 millimeters.
1 liter equals 1 cubic decimeter.

Square or Surface Measure

Square Kilo-meter	Square Hectometer or Hectare	Square Dekameter or Are	Square Meter or Centiare	Square Decimeter	Square Centimeter	Square Millimeter
1	100	10,000	1,000,000			
	1	100	10,000	1,000,000		
	.01	1	100	10,000	1,000 000	
	.0001	.01	1	100	10,000	1,000,000
	.000001	.0001	.01	1	100	10.000
		.000001	.0001	.01	1	100
			.000001	.0001	.01	1

1 square myriameter equals 100 square kilometers equals 100,000,000 square meters.

Cubic Measure

Cubic Dekameter	Cubic Meter	Cubic Decimeter	Cubic Centimeter	Cubic Millimeter
1	1 000	1.000.000	1,000 000 000	
.001	1	1 000	1,000,000	1,000.000,000
.000001	.001	1	1,000	1,000 000
.000000001	.000001	.001	1	1,000
	.000000001	.000001	.001	1

1 cubic meter equals 1 kiloliter equals 1 stere.

Meter equals 39.37 inches.
Square meter equals 1.550 square inches.
Liter or cube decimeter equals 61.022 cube inches.
Gram (weight of a cube centimeter of water) equals 15.432 grains.

Tables of Equivalents

Tables of Equivalents of United States Weights and Measures in corresponding Metric denominations:

Weights

1 Grain	is equivalent to	64.79892	Milligrams
1 Troy Ounce	"	31.10348	Grams
1 Avoirdupois Ounce	"	28.34953	Grams
1 Avoirdupois Pound	"	.45359	Kilogram
1 Net Ton of 2,000 pounds	"	.90718	Tonne
1 Gross Ton of 2,240 pounds	"	1.01605	Tonnes

Linear Measure

$\frac{1}{64}$ of an Inch	is equivalent to	.39688	Millimeter
1 Inch	"	2.54001	Centimeters
1 Foot	"	.304801	Meter
1 Yard	"	.914402	Meter
1 Statute Mile	"	1.60935	Kilometers
1 Nautical Mile	"	1.85325	Kilometers

Square Measure

1 Square Inch	is equivalent to	6.45163	Square Centimeters
1 Square Foot	"	.09290	Square Meter
1 Square Yard	"	.83613	Square Meter
1 Acre	"	.40470	Hectare
1 Square Mile	"	2.59000	Square Kilometers

Cubic Measure

1 Cubic Inch	is equivalent to	16.38716	Cubic Centimeters
1 Cubic Inch	"	.01639	Cubic Decimeter
1 Cubic Foot	"	.02832	Cubic Meter
1 Cubic Yard	"	.76456	Cubic Meter

Capacity Measure

1 Liquid Quart	is equivalent to	.94636	Liter
1 Gallon	"	3.78543	Liters
1 Gallon	"	.00379	Cubic Meter
1 Bushel	"	.35239	Hectoliter
1 Fluid Drachm	"	3.69671	Milliliters or Cubic Centimeters
1 Fluid Ounce	"	29.57370	Milliliters or Cubic Centimeters

Miscellaneous

1 Pound per Lineal Foot	is equivalent to	1.48816	Kilograms per Lineal Meter
1 Pound per Square Inch	"	.07031	Kilogram per Sq. Centimeter
1 Pound per Square Foot	"	4.88241	Kilograms per Square Meter
1 Pound per Cubic Foot	"	16.01837	Kilograms per Cubic Meter
1 Foot Pound	"	.13826	Kilogrammeter
1 United States Horsepower	"	1.01387	Metric Horsepower

Tables of Equivalents

Tables of Equivalents of Metric Weights and Measures in corresponding United States denominations:

Weights

1 Milligram	is equivalent to	.01543	Grain
1 Gram	"	.03215	Troy Ounce
1 Gram	"	.03527	Avoirdupois Ounce
1 Kilogram	"	2.20462	Avoirdupois Pounds
1 Tonne	"	1.10231	Net Tons of 2,000 Pounds
1 Tonne	"	.98421	Gross Tons of 2,240 Pound

Linear Measure

1 Millimeter	is equivalent to	2.51968	64ths of an Inch
1 Centimeter	"	.39370	Inch
1 Meter	"	3.280833	Feet
1 Meter	"	1.093611	Yards
1 Kilometer	"	.62137	Statute Mile
1 Kilometer	"	.53959	Nautical Mile

Square Measure

1 Square Centimeter	is equivalent to	.15500	Square Inch
1 Square Meter	"	10.76387	Square Feet
1 Square Meter	"	1.19599	Square Yards
1 Hectare	"	2.47104	Acres
1 Square Kilometer	"	.38610	Square Mile

Cubic Measure

1 Cubic Centimeter	is equivalent to	.06102	Cubic Inch
1 Cubic Decimeter	"	61.02338	Cubic Inches
1 Cubic Meter	"	35.31445	Cubic Feet
1 Cubic Meter	"	1.30794	Cubic Yards

Capacity Measure

1 Liter	is equivalent to	1.05668	Fluid Quarts
1 Liter	"	.26417	Gallon
1 Cubic Meter	"	264.17047	Gallons
1 Hectoliter	"	2.83774	Bushels
1 Milliliter or Cubic Centimeter	"	.27051	Fluid Drachm
1 Milliliter or Cubic Centimeter	"	.03381	Fluid Ounce

Miscellaneous

1 Kilogram per Lineal Meter	is equivalent to	.67197	Pound per Lineal Foot
1 Kilogram per Sq. Centimeter	"	14.22340	Pounds per Square Inch
1 Kilogram per Square Meter	"	.20482	Pound per Square Foot
1 Kilogram per Cubic Meter	"	.06243	Pound per Cubic Foot
1 Kilogrammeter	"	7.23300	Foot Pounds
1 Metric Horsepower	"	.98632	United States Horsepower

VELOCITY OF WATER in feet per second, due to heads from 0 to 6.99 feet.

Head.	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.802	1.134	1.389	1.604	1.793	1.965	2.122	2.268	2.406
.1	2.536	2.660	2.778	2.892	3.001	3.106	3.208	3.307	3.403	3.496
.2	3.587	3.675	3.762	3.846	3.929	4.010	4.090	4.167	4.244	4.319
.3	4.393	4.465	4.537	4.607	4.677	4.745	4.812	4.878	4.944	5.009
.4	5.072	5.135	5.198	5.259	5.320	5.380	5.440	5 498	5.557	5.614
.5	5.671	5.728	5.783	5.893	5.894	5.948	6 002	6 055	6.108	6.160
.6	6.212	6 264	6.315	6.366	6.416	6.466	6.516	6.565	6 614	6 662
.7	6.710	6.758	6 805	6.852	6.899	6.946	6 992	7.038	7.083	7.129
.8	7.173	7.218	7 263	7.307	7.351	7.394	7.438	7.481	7.524	7.566
.9	7.609	7.651	7.693	7.734	7.776	7.817	7 858	7.899	7.940	7.980
1.0	8.020	8.060	8.100	8.140	8.179	8.218	8.257	8.296	8.335	8.373
.1	8.412	8.450	8.488	8.526	8.563	8.601	8.638	8.675	8.712	8 749
.2	8.786	8 822	8.859	8.895	8.931	8.967	9.003	9.038	9 074	9.109
.3	9.144	9.180	9.214	9.249	9.284	9.319	9.353	9.387	9.422	9 456
.4	9.490	9.523	9.557	9.591	9.624	9.658	9.691	9.724	9.757	9.790
.5	9.823	9.855	9.888	9.920	9.953	9.985	10.017	10.049	10.081	10.113
.6	10.145	10.176	10.208	10.240	10.271	10.302	10.333	10.364	10.395	10.426
.7	10 457	10.488	10.518	10.549	10.579	10.610	10.640	10 670	10.700	10.730
.8	10.760	10.790	10 820	10 850	10.879	10.909	10.938	10.967	10.997	11.026
.9	11.055	11.084	11.113	11.142	11.171	11.200	11.228	11.257	11.285	11.314
2.0	11.342	11.371	11.399	11.427	11.455	11.483	11.511	11.539	11.567	11.595
.1	11.622	11.650	11.678	11.705	11.733	11.760	11.787	11.814	11.842	11.869
.2	11.896	11.923	11 950	11.977	12.004	12.030	12 057	12.084	12.110	12 137
.3	12.163	12.190	12.216	12.242	12.269	12.295	12.321	12 347	12 373	12.399
.4	12 425	12 451	12.477	12.502	12 528	12.554	12.579	12.605	12 630	12.656
.5	12.681	12.706	12.732	12.757	12.782	12.807	12.832	12 857	12.882	12.907
.6	12.932	12.957	12.982	13.007	13.031	13.056	13.081	13.105	13.130	13.154
.7	13.179	13.203	13.227	13.252	13.276	13.300	13.324	13.348	13.372	13.396
.8	13 420	13 444	13 468	13.492	13 516	13 540	13.563	13.587	13.611	13 634
.9	13.658	13.681	13.705	13.728	13.752	13.775	13.798	13.822	13.845	13.868
3.0	13.891	13.915	13 938	13.961	13.984	14.007	14.030	14.053	14.075	14.098
.1	14.121	14.144	14.166	14.189	14.212	14.234	14.257	14.280	14.302	14.325
.2	14.347	14.369	14 392	14.414	14 436	14.459	14.481	14.503	14.525	14.547
.3	14.569	14.591	14.613	14.635	14.657	14.679	14.701	14.723	14.745	14 767
.4	14.789	14.810	14.832	14.854	14 875	14.897	14.918	14.940	14 961	14.983
.5	15 004	15 026	15 047	15.069	15.090	15.111	15.132	15.154	15.175	15.196
.6	15 217	15.238	15.259	15.281	15.302	15.322	15.344	15.364	15.385	15.406
.7	15.427	15.448	15.469	15.490	15 510	15.531	15.552	15.572	15.593	15.614
.8	15.634	15.655	15 675	15.696	15.716	15.737	15.757	15.778	15.798	15.818
.9	15.839	15.859	15.876	15.899	15.920	15.940	15.960	15 980	16.000	16.020
4.0	16.040	16.060	16.080	16.100	16 120	16 140	16.160	16.180	16.200	16.220
.1	16.240	16 259	16.279	16.299	16 319	16 338	16.358	16.378	16.397	16.417
.2	16.437	16 456	16.476	16 495	16.515	16.534	16.554	16.573	16.592	16.612
.3	16.631	16.650	16.670	16.689	16.708	16.727	16.747	16 766	16.785	16.804
.4	16.823	16.842	16.862	16.881	16 900	16.919	16.938	16.957	16.976	16.994
.5	17.013	17.032	17.051	17.070	17.089	17.108	17.126	17.145	17 164	17.183
.6	17.201	17.220	17.239	17.257	17.276	17.295	17.313	17.332	17.350	17.369
.7	17.387	17.406	17.424	17.443	17.461	17.480	17.498	17.516	17.535	17.553
.8	17.571	17.590	17.608	17.626	17.644	17.663	17.681	17 699	17.717	17 735
.9	17.753	17.772	17.790	17.808	17.826	17.844	17.862	17.880	17.898	17.916
5.0	17.934	17.952	17.970	17.987	18.005	18.023	18.041	18.059	18 077	18.094
.1	18 112	18.130	18.148	18.165	18.183	18.201	18.218	18.236	18.254	18.271
.2	18.289	18.306	18.324	18.342	18 359	18 377	18.394	18.412	18.429	18 446
.3	18 464	18.481	18.499	18.516	18.533	18.551	18.568	18.585	18.603	18.620
.4	18.637	18.655	18.672	18.689	18.706	18 723	18.741	18 758	18.775	18.792
5	18.809	18.826	18 843	18.860	18.877	18 894	18 911	18 928	18 945	18.962
.6	18.979	18.996	19.013	19.030	19.047	19.064	19 081	19.098	19.114	19.131
.7	19.148	19 165	19.182	19 198	19.215	19 232	19.248	19.265	19.282	19.299
.8	19.315	19 332	19 348	19.365	19 382	19.398	19.415	19.431	19.448	19 464
.9	19.481	19.497	19.514	19.530	19.547	19.563	19.580	19.596	19.613	19.629
6.0	19.645	19.662	19.678	19.694	19.711	19.727	19.743	19.760	19.776	19.792
.1	19.808	19.825	19.841	19.857	19.873	19.889	19.906	19.922	19.938	19.954
.2	19.970	19.986	20 002	20 018	20.034	20 050	20.067	20.083	20.099	20 115
.3	20.131	20 147	20.162	20.178	20.194	20.210	20 226	20 242	20.258	20.274
.4	20.290	20.306	20 321	20.337	20.353	20.369	20.385	20.400	20.416	20.432
.5	20 448	20.463	20.479	20.495	20 510	20.526	20.542	20 557	20.573	20.589
.6	20 604	20.620	20 635	20 651	20.667	20.682	20.698	20 713	20.729	20 744
.7	20.760	20.775	20.791	20.806	20.822	20.837	20.853	20.868	20 883	20 899
.8	20 914	20 929	20 945	20.960	20 976	20.991	21.006	21.021	21.037	21 052
.9	21.067	21.083	21.098	21.113	21.128	21.144	21.159	21.174	21.189	21 204

VELOCITY OF WATER in feet per second, due to heads from 7 to 13.99 feet.

Head.	0	1	2	3	4	5	6	7	8	9
7.0	21.219	21.235	21.250	21.265	21.280	21.295	21.310	21 325	21.340	21.355
.1	21.370	21.386	21.401	21.416	21.431	21.446	21.461	21.476	21 491	21.506
.2	21.520	21 535	21.550	21.565	21.580	21.595	21.610	21 625	21.640	21.655
.3	21.669	21.684	21.699	21.714	21.729	21.743	21.758	21.773	21.788	21.803
.4	21 817	21.832	21.847	21 861	21.876	21.891	21.906	21.920	21 935	21.950
.5	21.964	21 979	21.993	22 008	22.023	22.037	22.052	22.066	22.081	22.096
.6	22.110	22 125	22.139	22 154	22.168	22.183	22.197	22 212	22.226	22.241
.7	22.255	22 270	22.284	22.298	22.313	22.327	22.342	22.356	22.370	22.385
.8	22 399	22.414	22.428	22 442	22 457	22.471	22.485	22.499	22.514	22.528
.9	22.542	22.557	22.571	22.585	22.599	22.614	22.628	22.642	22.656	22.670
8.0	22.685	22 699	22.713	22.727	22.741	22.755	22 769	22.784	22 798	22.812
.1	22.826	22 840	22.854	22.868	22.882	22.896	22.910	22.924	22.938	22.952
.2	22.966	22.980	22.994	23.008	23.022	23.036	23.050	23.064	23.078	23 092
.3	23.106	23.120	23.134	23 148	23.162	23 175	23.189	23.203	23.217	23.231
.4	23 245	23.259	23.272	23.286	23.300	23.314	23 328	23.341	23.355	23.369
.5	23 383	23.396	23.410	23.424	23.438	23.451	23.465	23 479	23.492	23.506
.6	23.520	23.534	23.547	23 561	23.574	23.588	23.602	23 615	23.629	23 643
.7	23.656	23.670	23.683	23.697	23.711	23.724	23.738	23 751	23.765	23.778
.8	23.792	23 805	23 819	23.832	23.846	23.859	23 873	23.886	23.900	23 913
.9	23.927	23.940	23.953	23.967	23.980	23.994	24.007	24.020	24.034	24.047
9.0	24.061	24 074	24.087	24.101	24.114	24.127	24 141	24.154	24.167	24.181
.1	24 194	24.207	24.220	24.234	24.247	24.260	24.274	24 287	24.300	24.313
.2	24.326	24.340	24.353	24.366	24.379	24 392	24.406	24.419	24.432	24.445
.3	24 458	24.471	24.485	24.498	24 511	24.524	24.537	24.550	24.563	24.576
.4	24.589	24.603	24 616	24.629	24.642	24.655	24.668	24.681	24.694	24.707
.5	24.720	24 733	24.746	24.759	24.772	24.785	24.798	24.811	24.824	24.837
.6	24.850	24.863	24.876	24.888	24.901	24.914	24.927	24.940	24.935	24.966
.7	24.979	24.992	25.005	25.017	25.030	25.043	25.056	25.069	25.082	25.094
.8	25.107	25.120	25.133	25.146	25.158	25.171	25.184	25.197	25.209	25.222
.9	25.235	25.248	25.260	25.273	25.286	25.299	25.311	25.324	25.337	25.349
10.0	25.362	25.375	25.387	25.400	25.413	25.425	25.438	25.451	25.463	25.476
.1	25.489	25.501	25.514	25.526	25.539	25.552	25.564	25.577	25.589	25.602
.2	25.614	25.627	25.640	25.652	25.665	25 677	25.690	25.702	25 715	25.728
.3	25.740	25.752	25.765	25.777	25 790	25.802	25 815	25.827	25.839	25.852
.4	25.864	25 877	25.889	25.902	25.914	25.926	25.939	25 951	25 964	25.976
.5	25.988	26.001	26.013	26.026	26.038	26.050	26.063	26.075	26.087	26.099
.6	26.112	26.124	26.136	26.149	26.161	26 173	26 186	26.198	26.210	26.222
.7	26.235	26.247	26.259	26.272	26.284	26.296	26.308	26.320	26 333	26.345
.8	26.357	26.369	26.381	26.394	26 406	26 418	26.430	26 442	26.454	26.467
.9	26.479	26.491	26.503	26.515	26.527	26.540	26.552	26.564	26.576	26.588
11.0	26.600	26.612	26.624	26.636	26.648	26 660	26.672	26.684	26.697	26 709
.1	26.721	26.733	26.745	26.757	26.769	26.781	26.793	26 805	26.817	26.829
.2	26.841	26.853	26.865	26.877	26.889	26.901	26.913	26.924	26.936	26.948
.3	26.960	26 972	26.984	26.996	27.008	27.020	27.032	27.044	27.056	27.067
.4	27.079	27.091	27.103	27.115	27.127	27.139	27.150	27.162	27.174	27.186
.5	27.198	27.210	27.221	27 233	27.245	27.257	27.269	27.280	27.292	27.304
.6	27.316	27.328	27.339	27.351	27.363	27 375	27.386	27.398	27.410	27.422
.7	27.433	27 445	27 457	27.468	27.480	27.492	27.504	27.515	27 527	27.539
.8	27.550	27.562	27.574	27.585	27.597	27.609	27.620	27.632	27 644	27.655
.9	27.667	27.678	27.690	27.702	27.713	27.725	27.736	27.748	27.760	27.771
12.0	27.783	27.794	27 806	27.817	27.829	27.841	27.852	27 864	27.875	27 887
.1	27.898	27.910	27.921	27.933	27.944	27.956	27 967	27.979	27.990	28.002
.2	28.013	28.025	28 036	28.048	28.059	28.071	28.082	28.094	28.105	28.117
.3	28.128	28.139	28.151	28.162	28.174	28.185	28.196	28.208	28.219	28.231
.4	28.242	28.253	28.265	28.276	28.288	28.299	28.310	28.322	28.333	28.344
.5	28.356	28.367	28.378	28 390	28.401	28.412	28.424	28.435	28.446	28.458
.6	28.469	28 480	28 491	28.503	28.514	28 525	28.537	28.548	28.559	28.570
.7	28.582	28 593	28.604	28.615	28.627	28.638	28.649	28 660	28.672	28.683
.8	28.694	28.705	28.716	28.727	28.739	28.750	28 761	28.772	28 783	28.795
.9	28.806	28.817	28.828	28.839	28.850	28.862	28.873	28.884	28.895	28.906
13.0	28.917	28.928	28.939	28.951	28.962	28.973	28 984	28.995	29.006	29.017
.1	29.028	29.0 9	29.050	29.061	29.073	29.084	29 095	29.106	29.117	29.128
.2	29.139	29.150	29.161	29 172	29.183	29 194	29.205	29.216	29.227	29.238
.3	29.249	29.260	29 271	29.282	29.293	29.304	29.315	29.3 6	29.337	29.348
.4	29.359	29.370	29.381	29.392	29.403	29 413	29.424	29.435	29.446	29.457
.5	29.468	29 479	29.490	29.501	29.512	29.523	29.533	29.544	29.555	29.566
.6	29 577	29.588	29.599	29 610	29.620	29 631	29.642	29.653	29.664	29.675
.7	29.686	29 696	29.707	29 718	29.729	29.740	29.751	29.761	29 772	29.783
.8	29.794	29.805	29.815	29.826	29.837	29.848	29 858	29 869	29.880	29.891
.9	29.901	29.912	29.923	29 934	29.944	29.955	29.966	29.977	29.987	29.998

VELOCITY OF WATER in feet per second, due to heads from 14 to 20.99 feet.

Head.	0	1	2	3	4	5	6	7	8	9
14.0	30.009	30.020	30.030	30.041	30.052	30.062	30.073	30.084	30.[illegible]	[illegible].105
.1	30.116	30.126	30.137	30.148	30.159	30.169	30.180	20.190	30.201	30.212
.2	30.222	30.233	30.244	30.254	30.265	30.276	30.286	30.297	30.307	30.318
.3	30.329	30.339	30.350	30.360	30.371	30.382	30.392	30.403	30.413	30.424
.4	30.435	30.445	30.456	30.466	30.477	30.487	30.498	30.508	30.519	30.529
.5	30.540	30.551	30.561	30.572	30.582	30.593	30.603	30.614	30.624	30.635
.6	30.645	30.656	30.666	30.677	30.687	30.698	30.708	30.719	30.729	30.739
.7	30.750	30.760	30.771	30.781	30.792	30.802	30.813	30.823	30.838	30.844
.8	30.854	30 865	30.875	30.886	30.896	30.906	30.917	30.927	30.938	30.948
.9	30.958	30.969	30.979	30.990	31.000	31.010	31.021	31.031	31.041	31.052
15.0	31.062	31.072	31.083	31.093	31.103	31.114	31.124	31.134	31.145	31.155
.1	31.165	31.176	31.186	31.196	31.207	31.217	31.227	31.238	31.248	31.258
.2	31.268	31.279	31.289	31.299	31.310	31.320	31.330	31.340	31.351	31.361
.3	31.371	31.381	31.392	31.402	31.412	31.422	31.433	31.443	31.453	31.463
.4	31.474	31.484	31.494	31.504	31.514	31.525	31.535	31.545	31.555	31.565
.5	31.576	31.586	31.596	31.606	31.616	31.626	31.637	31.647	31.657	31.667
.6	31.677	31.687	31.698	31.708	31.718	31.728	31.738	31.748	31.758	31.768
.7	31.779	31.789	31.799	31.809	31.819	31.829	31.839	31.849	31.859	31.870
.8	31.880	31.890	31.900	31.910	31.920	31.930	31.940	31.950	31.960	31.970
.9	31.980	31.990	32.000	32.011	32.021	32.031	32.041	32.051	32.061	32.071
16.0	32.081	32.091	32.101	32.111	32.121	32.131	32.141	32.151	32.161	32.171
.1	32.181	32.191	32.201	32.211	32.221	32 231	32.241	32.251	32.261	32.271
.2	32.281	32.291	32.301	32.311	32.321	32.330	32.340	32.350	32.360	32.370
.3	32.380	32.390	32.400	32.410	32.420	32.430	32.440	32.450	32.460	32.470
.4	32.480	32.489	32.499	32.509	32.519	32.529	32.539	32.549	32.559	32.569
.5	32.579	32.588	32.598	32.608	32.618	32.628	32 637	32 647	32.657	32.667
.6	32.677	32.687	32.696	32.706	32.716	32.726	32.736	32.746	32.755	32.765
.7	32.775	32.785	32.795	32.804	32.814	32.824	32.834	32.844	32.854	32.863
.8	32.873	32.883	32.893	32.903	32.912	32.922	32.932	32.941	32.951	32.961
.9	32.971	32.980	32.990	33.000	33.010	33.019	33.029	33.039	33.049	33.058
17.0	33.068	33.078	33.088	33.097	33.107	33.117	33.126	33.136	33.146	33.156
.1	33.165	33.175	33.185	33.194	33.204	33.214	33.223	33.233	33.243	33.252
.2	33.262	33.272	33.281	33 291	33.301	33.310	33.320	33.330	33.339	33.349
.3	33.359	33.368	33.378	33.388	33.397	33.407	33.416	33.426	33.436	33.445
.4	33 455	33.465	33.474	33.484	33.493	33.503	33.513	33.522	33.532	33.541
.5	33.551	33.560	33.570	33.580	33.589	33 599	33.608	33 618	33.628	33.637
.6	33.647	33.656	33.666	33.675	33.685	33.694	33.704	33.713	33.723	33.733
.7	33.742	33.752	33.761	33.771	33.780	33.790	33.799	33.809	33.818	33.828
.8	33.837	33 847	33.856	33.866	33.875	33.885	33.894	33.904	33.913	33.923
.9	33.932	33.942	33.951	33.961	33.970	33.980	33.989	33.998	34.008	34.017
18.0	34.027	34.036	34.046	34.055	34.065	34.074	34 083	34.093	34.102	34.112
.1	34.121	34.131	34.140	34.149	34.159	34.168	34.178	34.187	34 197	34.206
.2	34.215	44.225	34.234	34.244	34.253	34.262	34.272	34.281	34.290	34.300
.3	34.309	34.319	34.328	34.337	34.347	34.356	34.365	34.375	34.384	34.393
.4	34.403	34.412	34.422	34.431	34.440	34.450	34.459	34.468	34.478	34.487
.5	34.496	34.505	34.515	34.524	34.533	34.543	34.552	34.561	34.571	34.580
.6	34.589	34.599	34.608	34.617	34.626	34.636	34.645	34.654	34.664	34.673
.7	34.682	34.691	34.701	34.710	34.719	34.728	34.738	34.747	34.756	34.766
.8	34.775	34.784	34.793	34.802	34.812	34.821	34.830	34.839	34.849	34.858
.9	34.867	34.876	34.886	34.895	34.904	34.913	34.922	34.932	34.941	34.950
19.0	34.959	34.968	34.978	34.987	34.996	35.005	35.014	35.024	35 033	35.042
.1	35.051	35.060	35.069	35.079	35.088	35.097	35.106	35.115	35.124	35.134
.2	35.143	35.152	35.161	35.170	35.179	35.188	35.198	35.207	35.216	35.225
.3	35.234	35.243	35.252	35.262	35.271	35.280	35.289	35.298	35.307	35.316
.4	35.325	35.334	35.344	35.353	35.362	35.371	35.380	35.389	35.398	35.407
.5	35.416	35.425	35.434	35.443	35.453	35.462	35.471	35.480	35.489	35.498
.6	35.507	35.516	35.525	35.534	35.543	35.552	35.561	35.570	35.579	35 588
.7	35.597	35.606	35.615	35.624	35.634	35.643	35.652	35.661	35.670	35.679
.8	35.688	35.697	35.706	35.715	35.724	35.733	35.742	35.751	35.760	35.769
.9	35.778	35.787	35.796	35 805	35.814	35.823	35.832	35.841	35.849	35.858
20.0	35.867	35.876	35.885	35.894	35.903	35 912	35.921	35.930	35.939	35.948
.1	35.957	35.966	35.975	35.984	35.993	36.002	36.011	36.020	36.028	36.037
.2	36.046	36.055	36.064	36.073	36.082	36.091	36.100	36.109	36.118	36.127
.3	36.135	36.144	36.153	36.162	36.171	36.180	36.189	36.198	36.207	36.215
.4	36.224	36.233	36.242	36.251	36.260	36.269	36.278	36.286	36.295	36.304
.5	36.313	36.322	36.331	36.340	36.348	36.357	36.366	36.375	36.384	36.393
.6	36.401	36.410	36.419	36.428	36.437	36.446	36.454	36.463	36.472	36.481
.7	36.490	36.499	36.507	36.516	36.525	36.534	36.543	36.551	36.560	36.569
.8	36.578	36.587	36.595	36.604	36.613	36.622	36.630	36.639	36.648	36.657
.9	36.666	36.674	36.683	36.692	36.701	36.709	36.718	36.727	36.736	36.744

VELOCITY OF WATER in feet per second, due to heads from 21 to 27.99 feet.

Head.	0	1	2	3	4	5	6	7	8	9
	36.453	36.762	36.771	36.779	36.788	36.797	36.806	36.814	36.823	36.832
.1	36.841	36.849	36.858	36.867	36.875	36.884	36.893	36.902	36.910	36.919
.2	36.928	36.936	36.945	36.954	36.963	36.971	36.980	36.989	36.997	37.006
.3	37.015	37.023	37.032	37.041	37.049	37.058	37.067	37.076	37.084	37.093
.4	37.102	37.110	37.119	37.128	37.136	37.145	37.154	37.162	37.171	37.179
.5	37.188	37.197	37.205	37.214	37.223	37.231	37.240	37.249	37.257	37.266
.6	37.275	37.283	37.292	37.300	37.309	37.318	37.326	37.335	37.343	37.352
.7	37.361	37.369	37.378	37.387	37.395	37.404	37.412	37.421	37.430	37.438
.8	37.447	37.455	37.464	37.472	37.481	37.490	37.498	37.506	37.515	37.524
.9	37.532	37.541	37.550	37.558	37.567	37.575	37.584	37.592	37.601	37.610
22.0	37.618	37.627	37.635	37.644	37.652	37.661	37.669	37.678	37.686	37.695
.1	37.703	37.712	37.721	37.729	37.738	37.746	37.755	37.763	37.772	37.780
.2	37.789	37.797	37.806	37.814	37.823	37.832	37.840	37.848	37.857	37.865
.3	37.874	37.882	37.891	37.899	37.908	37.916	37.925	37.933	37.942	37.950
.4	37.959	37.967	37.975	37.984	37.992	38.001	38.009	38.018	38.026	38.035
.5	38.043	38.052	38.060	38.068	38.077	38.085	38.094	38.102	38.111	38.119
.6	38.128	38.136	38.144	38.153	38.161	38.170	38.178	38.187	38.195	38.203
.7	38.212	38.220	38.229	38.237	38.246	38.254	38.262	38.271	38.279	38.288
.8	38.296	38.304	38.313	38.321	38.330	38.338	38.346	38.355	38.363	38.371
.9	38.380	38.388	38.397	38.405	38.413	38.422	38.430	38.438	38.447	38.455
23.0	38.464	38.472	38.480	38.489	38.497	38.505	38.514	38.522	38.530	38.539
.1	38.547	38.555	38.564	38.572	38.580	38.589	38.597	38.605	38.614	38.622
.2	38.630	38.638	38.647	38.655	38.664	38.672	38.680	38.689	38.697	38.705
.3	38.714	38.722	38.730	38.738	38.747	38.755	38.763	38.772	38.780	38.788
.4	38.797	38.805	38.813	38.821	38.830	38.838	38.846	38.855	38.863	38.871
.5	38.879	38.888	38.896	38.904	38.912	38.921	38.929	38.937	38.945	38.954
.6	38.962	38.970	38.978	38.987	38.995	39.003	39.011	39.020	39.028	39.036
.7	39.044	39.053	39.061	39.069	39.077	39.086	39.094	39.102	39.110	39.119
.8	39.127	39.135	39.143	39.151	39.160	39.168	39.176	39.184	39.192	39.201
.9	39.209	39.217	39.225	39.233	39.242	39.250	39.258	39.266	39.274	39.283
24.0	39.291	39.299	39.307	39.315	39.324	39.332	39.340	39.348	39.356	39.364
.1	39.373	39.381	39.389	39.397	39.405	39.413	39.422	39.430	39.438	39.446
.2	39.454	39.462	39.470	39.479	39.487	39.495	39.503	39.511	39.519	39.527
.3	39.536	39.544	39.552	39.560	39.568	39.576	39.584	39.592	39.601	39.609
.4	39.617	39.625	39.633	39.641	39.649	39.657	39.666	39.674	39.682	39.690
.5	39.698	39.706	39.714	39.722	39.730	39.738	39.747	39.755	39.763	39.771
.6	39.779	39.787	39.795	39.803	39.811	39.819	39.827	39.835	39.844	39.852
.7	39.860	39.868	39.876	39.884	39.892	39.900	39.908	39.916	39.924	39.932
.8	39.940	39.948	39.956	39.964	39.972	39.981	39.989	39.997	40.005	40.013
.9	40.021	40.029	40.037	40.045	40.053	40.061	40.069	40.077	40.085	40.093
25.0	40.101	40.109	40.117	40.125	40.133	40.141	40.149	40.157	40.165	40.173
.1	40.181	40.189	40.197	40.205	40.213	40.221	40.229	40.237	40.245	40.253
.2	40.261	40.269	40.277	40.285	40.293	40.301	40.309	40.317	40.325	40.333
.3	40.341	40.349	40.357	40.365	40.373	40.381	40.389	40.397	40.405	40.413
.4	40.421	40.428	40.436	40.444	40.452	40.460	40.468	40.476	40.484	40.492
.5	40.500	40.508	40.516	40.524	40.532	40.540	40.548	40.556	40.563	40.571
.6	40.579	40.587	40.595	40.603	40.611	40.619	40.627	40.635	40.643	40 651
.7	40.659	40.666	40.674	40.682	40.690	40.698	40.706	40.714	40.722	40 730
.8	40.738	40.745	40.753	40.761	40.769	40.777	40.785	40.793	40.801	40.809
.9	40.816	40.824	40.832	40.840	40.848	40.856	40.864	40.872	40.879	40.887
26.0	40.895	40.903	40.911	40.919	40.927	40.934	40.942	40.950	40.958	40 966
.1	40.974	40.982	40.989	40.997	41.005	41.013	41.021	41.029	41.036	41.044
.2	41.052	41.060	41.068	41.076	41.083	41.091	41.099	41.107	41.115	41.123
.3	41.130	41.138	41.146	41.154	41.162	41.169	41.177	41.185	41.193	41.201
.4	41.209	41.216	41.224	41.232	41.240	41.248	41.255	41.263	41.271	41.279
.5	41.287	41.294	41.302	41.310	41.318	41.325	41.333	41.341	41.349	41 357
.6	41.364	41.372	41.380	41.388	41.395	41.403	41.411	41.419	41.426	41.434
.7	41.442	41.450	41.458	41.465	41.473	41.481	41.489	41.496	41.504	41.512
.8	41.520	41.527	41.535	41.543	41.551	41.558	41.566	41.574	41.581	41.589
.9	41.597	41.605	41.612	41.620	41.628	41.636	41.643	41.651	41.659	41.666
27.0	41.674	41.682	41.690	41.697	41.705	41.713	41.720	41.728	41.736	41.744
.1	41.751	41.759	41.767	41.774	41.782	41.790	41.797	41.805	41.813	41.821
.2	41.828	41.836	41.844	41.851	41.859	41.867	41.874	41.882	41.890	41.897
.3	41.905	41.913	41.920	41.928	41.936	41.943	41.951	41.959	41.967	41.974
.4	41.982	41.989	41.997	42.005	42.012	42.020	42.028	42.035	42.043	42.051
.5	42.058	42.066	42.074	42.081	42.089	42.096	42.104	42.112	42.119	42.127
.6	42.135	42.142	42.150	42.158	42 165	42.173	42.180	42.188	42.196	42 203
.7	42.211	42.219	42 226	42.234	42.241	42.249	42.257	42.264	42.272	42.279
.8	42.287	42 295	42.302	42.310	42.317	42.325	42.333	42.340	42 348	42.355
.9	42.363	42.371	42.378	42.386	42.393	42.401	42.409	42.416	42.424	42.431

VELOCITY OF WATER in feet per second, due to heads from 28 to 34.99 feet.

Head.	0	1	2	3	4	5	6	7	8	9
28.0	42.439	42.446	42.454	42.462	42.469	42.477	42.484	42.492	42.499	42.507
.1	42.515	42.522	42.530	42.537	42.545	42.552	42.560	42.568	42.575	42.583
.2	42.590	42.598	42.605	42.613	42.620	42.628	42 635	42.643	42.651	42.658
.3	42.666	42.673	42.681	42.688	42 696	42.703	42.711	42.718	42.726	42.733
.4	42.741	42.748	42.756	42.764	42.771	42.779	42 786	42.794	42.801	42.809
.5	42.816	42.824	42 831	42.839	42.846	42.854	42.861	42.869	42.876	42.884
.6	42.891	42.899	42.906	42.914	42.921	42.929	42 936	42.944	42.951	42.959
.7	42.966	42 974	42.981	42.989	42.996	43.004	43.011	43.018	43.026	43.033
.8	43.041	43.048	43.056	43.063	43.071	43.078	43.086	43.093	43.101	43.108
.9	43.116	43.123	43.130	43.138	43.145	43.153	43.160	43.168	43.175	43.183
29.0	43.190	43.198	43.205	43.212	43.220	43.227	43.235	43.243	43.250	43.257
.1	43.264	43.272	43.279	43.287	43.294	43.302	43.309	43.316	43.324	43.331
.2	43.339	43.346	43.354	43.361	43.368	43.376	43 383	43.391	43.398	43.405
.3	43.413	43.420	43.428	43.435	43.443	43.450	43.457	43.465	43.472	43.480
.4	43.487	43.494	43.502	43.509	43.517	43.524	43.531	43.539	43.546	43.553
.5	43 561	43.568	43.576	43.583	43.590	43.598	43.605	43.612	43.620	43 627
.6	43.635	43.642	43.649	43.657	43.664	43.671	43.679	43.686	43.694	43.701
.7	43.708	43.716	43.723	43.730	43.738	43.745	43.752	43.760	43.767	43 774
.8	43.782	43.789	43.796	43.804	43 811	43.818	43.826	43.833	43.840	43.848
.9	43.855	43.862	43.870	43.877	43.884	43.892	43 899	43.906	43.914	43 921
30.0	43.928	43.936	43.943	43.950	43.958	43.965	43.972	43.980	43.987	43.994
.1	44.002	44.009	44.016	44.024	44.031	44.038	44.045	44.053	44.060	44.067
.2	44.075	44.082	44.089	44.097	44.104	44.111	44.118	44.126	44.133	44.140
.3	44.148	44.155	44.162	44.169	44.177	44.184	44.191	44.198	44.206	44.213
.4	44.220	44.228	44.235	44.242	44.249	44.257	44.264	44.271	44.278	44.286
.5	44.293	44.300	44.308	44.315	44.322	44.329	44.337	44.344	44.351	44.358
.6	44.366	44.373	44.380	44.387	44.395	44.402	44.409	44.416	44.423	44.431
.7	44.438	44.445	44.452	44.460	44.467	44.474	44 481	44.489	44.496	44.503
.8	44.510	44.518	44.525	44.532	44.539	44.546	44.554	44.561	44.568	44.575
.9	44.582	44.590	44.597	44.604	44.611	44.619	44.626	44.633	44.640	44.647
31.0	44.655	44 662	44.669	44.676	44.683	44.691	44.698	44.705	44.712	44.719
.1	44.727	44.734	44.741	44.748	44.755	44.762	44.770	44.777	44.784	44.791
.2	44.798	44.806	44.813	44.820	44.827	44.834	44.841	44.849	44.856	44.863
.3	44.870	44.877	44.884	44.892	44.899	44.906	44.913	44.920	44.927	44.935
.4	44.942	44.949	44.956	44.963	44.970	44.978	44.985	44.992	44.999	45.006
.5	45.013	45.020	45.028	45.035	45.042	45.049	45.056	45.063	45.070	45.078
.6	45.085	45.092	45.099	45.106	45.113	45.120	45.127	45.135	45.142	45.149
.7	45.156	45 163	45.170	45.177	45.184	45.192	45.199	45.206	45.213	45.220
.8	45.227	45.234	45.241	45.248	45.256	45.263	45.270	45.277	45.284	45.291
.9	45.298	45.305	45.312	45.319	45.327	45.334	45.341	45.348	45.355	45.362
32.0	45.369	45.376	45.383	45.390	45.397	45.405	45.412	45.419	45.426	45.433
.1	45.440	45.447	45.454	45.461	45.468	45.475	45.482	45.489	45.497	45.504
.2	45.511	45.518	45.525	45.532	45.539	45.546	45.553	45.560	45.567	45.574
.3	45.581	45 588	45.595	45.602	45.609	45.617	45.624	45.631	45.638	45.645
.4	45.652	45.659	45.666	45.673	45.680	45 687	45.694	45.701	45.708	45.715
.5	45.722	45.729	45.736	45.743	45.750	45.757	45.764	45.771	45.778	45.785
.6	45.792	45.799	45.807	45.814	45.821	45.828	45.835	45.842	45.849	45.856
.7	45.863	45.870	45.877	45.884	45.891	45 898	45.905	45.912	45.919	45.926
.8	45.933	45.940	45.947	45.954	45 961	45.968	45.975	45.982	45.989	45.996
.9	46.003	46.010	46.017	46.024	46.031	46.038	46.045	46.052	46.059	46.066
33.0	46.073	46.080	46.086	46.093	46.100	46.107	46.114	46.121	46.128	46.135
.1	46.142	46.149	46.156	46.163	46.170	46.177	46.184	46.191	46.198	46.205
.2	46.212	46.219	46.226	46.233	46.240	46.247	46.254	46.261	46.268	46.275
.3	46.281	46.288	46.295	46.302	46.309	46.316	46.323	46.330	46.337	46.344
.4	46.351	46.358	46.365	46.372	46.379	46.386	46.393	46.399	46.406	46.413
.5	46.420	46.427	46.434	46.441	46.448	46.455	46.462	46.469	46.476	46.483
.6	46.489	46.496	46.503	46.510	46.517	46.524	46.531	46.538	46.545	46.552
.7	46.559	46.566	46.572	46.579	46.586	46.593	46.600	46.607	46.614	46.621
.8	46.628	46.635	46.642	46.648	46.655	46.662	46.669	46.676	46.683	46.690
.9	46.697	46.703	46.710	46.717	46.724	46.731	46.739	46.745	46.752	46.759
34.0	46.765	46.772	46.779	46.786	46.793	46.800	46.807	46.814	46 820	46.827
.1	46.834	46.841	46.848	46 855	46.862	46 868	46.875	46.882	46.889	46.896
.2	46.903	46.910	46.916	46.923	46.930	46.937	46.944	46.951	46.958	46.964
.3	46.971	46.978	46.985	46.992	46.999	47.005	47.012	47.019	47.026	47.033
.4	47.040	47.047	47.053	47.060	47.067	47.074	47.081	47.088	47.094	47.101
.5	47.108	47.115	47.122	47.128	47.135	47 142	47.149	47.156	47.163	47.169
.6	47.176	47.183	47.190	47.197	47.203	47.210	47.217	47.224	47.231	47.238
.7	47.244	47.251	47.258	47.265	47.272	47.278	47.285	47.292	47.299	47.306
.8	47.312	47.319	47.326	47.333	47.340	47.346	47.353	47.360	47.367	47.374
.9	47.380	47.387	47.394	47.401	47.407	47.414	47.421	47.428	47.435	47.441

Velocity of Water

Table giving velocity of water in feet per second, and the cubic feet of water per minute, to develop one horse-power at 80 per cent. duty under heads from 1 to 108 feet.

Head	Velocity	Cubic Feet	Head	Velocity	Cubic Feet	Head	Velocity	Cubic Feet
1	8.02	661.765	37	48.78	17.886	73	68.53	9.065
2	11.34	330.883	38	49.44	17.415	74	69.00	8.943
3	13.89	220.589	39	50.09	16.968	75	69.46	8.822
4	16.04	165.441	40	50.72	16.544	76	69.92	8.707
5	17.92	132.353	41	51.35	16.141	77	70.38	8.594
6	19.65	110.294	42	51.98	15.756	78	70.84	8.484
7	21.22	94.538	43	52.59	15.390	79	71.29	8.377
8	22.68	82.720	44	53.20	15.040	80	71.74	8.272
9	24.06	73.529	45	53.80	14.706	81	72.19	8.170
10	25.36	66.177	46	54.40	14.368	82	72.63	8.070
11	26.60	60.160	47	54.99	14.080	83	73.07	7.973
12	27.78	55.147	48	55.57	13.787	84	73.51	7.878
13	28.92	50.905	49	56.14	13.505	85	73.95	7.785
14	30.01	47.269	50	56.71	13.236	86	74.38	7.695
15	31.06	44.118	51	57.27	12.976	87	74.81	7.606
16	32 08	41.360	52	57.84	12.726	88	75.24	7.520
17	33.07	38.927	53	58.39	12.486	89	75.67	7.436
18	34.03	36.765	54	58.93	12.255	90	76.09	7.353
19	34.96	34.830	55	59.48	12.032	91	76.51	7.272
20	35.87	33.088	56	60.01	11.817	92	76.93	7.193
21	36.75	31.513	57	60.56	11.610	93	77.35	7.116
22	37.61	30.080	58	61.08	11.410	94	77.76	7.040
23	38.46	28.772	59	61.61	11.216	95	78.18	6.966
24	39.29	27.574	60	62.12	11.029	96	78.59	6.893
25	40.10	26.471	61	62.71	10.849	97	79.00	6.822
26	40.89	25.453	62	63.15	10.674	98	79.40	6.753
27	41.67	24.510	63	63.66	10 504	99	79.81	6.685
28	42.44	23.634	64	64.16	10.340	100	80.22	6.618
29	43.19	22.819	65	64.66	10.181	101	80.61	6.552
30	43.93	22.059	66	65.16	10.027	102	81.01	6.487
31	44.65	21.347	67	65.65	9.877	103	81.40	6.425
32	45.37	20.680	68	66.14	9.732	104	81.80	6.363
33	46.07	20.053	69	66.62	9.591	105	82.19	6.303
34	46.77	19.464	70	67.11	9.454	106	82.58	6.243
35	47.45	18.908	71	67.58	9.321	107	82.97	6.185
36	48.12	18.382	72	68.06	9.191	108	83.35	6.127

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